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U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF SOILS—MILTON WHITNEY, Chief.

IN COOPERATION WITH THE UNIVERSITY OF CALIFORNIA AGRICULTURAL  
EXPERIMENT STATION, THOMAS F. HUNT, DIRECTOR;  
CHARLES F. SHAW, IN CHARGE SOIL SURVEY

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RECONNOISSANCE SOIL SURVEY OF THE  
SACRAMENTO VALLEY, CALIFORNIA.

BY

L. C. HOLMES, J. W. NELSON, AND PARTY

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MACY H. LAPHAM, INSPECTOR, WESTERN DIVISION.

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[Advance Sheets—Field Operations of the Bureau of Soils, 1913.]



WASHINGTON:  
GOVERNMENT PRINTING OFFICE.  
1915.

SOIL SURVEY.

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## LETTER OF TRANSMITTAL

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U. S. DEPARTMENT OF AGRICULTURE,  
BUREAU OF SOILS,  
*Washington, D. C., December 19, 1914.*

SIR: During the field season of 1913 a reconnoissance soil survey was made of the Sacramento Valley, Cal. This work was done in cooperation with the University of California Agricultural Experiment Station, and the selection of the area was made after conference with State officials. Messrs. L. C. Holmes and J. W. Nelson, the latter a member of the university staff, had charge of the work in the field and were assisted by Messrs. E. B. Watson and G. L. Harrington, of the U. S. Department of Agriculture, and Messrs. J. E. Guernsey and C. J. Zinn, of the University of California.

I have the honor to transmit herewith the manuscript report and map covering this area and to recommend their publication as advance sheets of Field Operations of the Bureau of Soils for 1913, as provided by law.

Respectfully,

MILTON WHITNEY,  
*Chief of Bureau.*

Hon. D. F. HOUSTON,  
*Secretary of Agriculture.*



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### MAP.

Soil map, reconnaissance survey, Sacramento Valley sheet, California.

# RECONNOISSANCE SOIL SURVEY OF THE SACRAMENTO VALLEY, CALIFORNIA.

By L. C. HOLMES, J. W. NELSON, and Party.

## DESCRIPTION OF THE AREA.

### GEOGRAPHY.

The Great Interior Valley of California occupies the central belt of the State, its axis lying approximately parallel to the eastern and western boundaries of the State and extending from the city of Redding, in latitude  $40^{\circ} 35'$  approximately, southward to some distance south of Bakersfield, ending in latitude  $35^{\circ} 10'$ , approximately. Its length is about 380 miles and its width will average about 45 miles, the variation in width throughout its whole length being relatively small. Its eastern side is formed by the western slope of the Sierra Nevada Mountains and its western side by the eastern slope of the Coast Ranges. It is inclosed around its northern end by the so-called Klamath Mountains, which may be considered, for the purposes of this report, as merely the merging of the Coast Ranges with the Sierras and Cascade Mountains; and around its southern end by the so-called Tehachapi Mountains, which likewise may be considered as the merging, in this part of the State, of the Sierra Nevada and Coast Ranges. The boundary of the valley on all sides is relatively sharp, somewhat more so on the western than on the eastern side, however. The ends are rounded or blunt also, rather than sharp-pointed.

At a point about half way between the northern and southern ends of the valley there is a break in the Coast Ranges through which the drainage waters have outlet from the valley. In fact, however, the bottom of the opening across the ranges is lower than sea-level, so that the sea advances as an arm across them and into the valley. The rivers of the valley, therefore, enter the sea within the valley and do not extend, as rivers, across the inclosing ranges. Elsewhere the inclosing ranges are practically unbroken.



FIG. 1.—Sketch map showing location of the Sacramento Valley reconnaissance.



The valley is drained longitudinally, the northern half by the Sacramento River, entering the valley as a large stream through a gorge in the inclosing ranges at its extreme northern end, the southern half by the San Joaquin, formed within the valley by the union of a number of streams entering from the inclosing mountains, mainly from the Sierras. The name San Joaquin is applied, beyond the boundary of the valley, to one of the main streams flowing in from the Sierras. The two main streams enter the sea together just inside the break in the Coast Ranges just described.

The Sacramento Valley as defined in this report includes the north half of the Great Interior Valley of California, the part drained by the Sacramento River, and this report covers approximately the whole of it. It has an area of 6,274 square miles, or 4,015,360 acres. A small part of the extreme northern end and small areas near the mouth of the river are not included. The reader is referred to the accompanying map for details.

#### TOPOGRAPHY.

The Sacramento Valley is a structural trough formed by the uplift of the mountains surrounding it. Since formation its original floor has been deeply buried by an accumulation of rock waste carried into it from the mountains. Some of this material was laid down in salt or brackish water, some in fresh water, and some has been distributed as alluvial fan and alluvial material on a land surface by the streams that enter and traverse the valley. Practically the whole of the material forming the surface and extending far below the depth reached by plant roots, below the soil depth, therefore, consists of alluvial fan and alluvial material. It is only along the borders of the valley that the older material is found. In a few places there are remnants of lava flows that extended into the valley, but like the older water-laid deposits, they are exposed only along the outer boundaries of the area.

The alluvial-fan deposits consist of an older and a younger series of deposits, the older series being laid down at a time when the valley floor lay nearer sea level than at present and constituting the older valley-filling material, while the younger series is still in process of formation. In the northern end of the valley from the latitude of Chico northward the old alluvial fans from opposite sides met in the middle of the valley, filling it up to a higher elevation than farther south. Southward, where the valley is wider, the old fans reached the axis of the valley, if at all, only with their lower, flatter ends, where they were later covered by the alluvial deposits of the Sacramento River and the younger fans. Their higher parts are exposed along the outer borders of the valley, while their lower, flatter ends are buried. The exposed parts of the older series have been eroded into a topog-

raphy that, compared with that of the younger, is somewhat hilly. It can not be described, however, as more than rolling and in most places is merely undulating. The northern end of the valley and that part of it lying adjacent to the inclosing mountains is the highest and as a rule the roughest. The Sacramento River has cut a valley in the older material from Red Bluff southward to the vicinity of Hamilton City. Below this place the river valley widens rapidly to include the whole central part of the larger valley, where the river has formed a flood plain by deposition from the first rather than by erosion and deposition in its own eroded trough. At Tehama and Vina the river valley is narrowest, being about 2 miles in width. Adjacent to the valley boundary and along the foot of the inclosing ranges the country is rolling. Between these two more rolling belts the topography is smooth to undulating. Along the eastern side of the valley the old fans still occupy a rather broad belt, reaching from the foothills westward to the Feather River. They are eroded to a topography much like that of the old fans in the northern end of the valley. Along the western side of the valley, however, the belt of old fans now exposed and forming a part of the surface is very narrow. In fact, it is almost obliterated south of Orland. On the east side modern alluvial fans are very small, barely existing at all. On the west side, however, they dominate the topography south of Orland. The prominent ones on this side are those at and south of Orland, the broad, flat one at Willows, the higher, steeper one at Arbuckle, a broad and rather flat one at Woodland, and a similar one east of Winters. The Orland and Arbuckle fans are built in part of gravel, while the Willows and Woodland and Winters fans are made of finer-grained material.

The Marysville Buttes, a remnant of a volcanic cone, stand in the middle of the valley, a few miles northwest of Marysville. This cone has been thoroughly eroded, and at present consists of merely a group of hills, some of them rising to a height slightly in excess of 2,000 feet above the adjacent parts of the valley. The Montezuma Hills consist of a remnant of eroded sedimentary deposits, standing well out in the valley near the southwestern part of the area covered by the survey. In the axial belt of the valley south of the latitude of Chico the Sacramento is an aggrading stream rather than an eroding stream. It has built natural levees, therefore, along its banks, which stand a few feet higher than the land back of them and between them and the riverward termination of the alluvial fans built by the streams entering the valley. These low areas are called "basins," the most important being the Sutter Basin, on the east side of the river south of the Marysville Buttes, the American Basin on the east side just above Sacramento, the Colusa Basin on the west side of the river opposite the Sutter Basin, and the Yolo Basin across the river

from Sacramento. The Mormon Basin is a part of the Colusa Basin. The elevation of the area surveyed, aside from the relatively local higher and rougher portions of the Marysville Buttes, ranges from a maximum of about 500 feet in the northern part to sea level in the southwestern part.

#### POPULATION.

The population of the Sacramento Valley, according to the 1910 census, is about 170,000. Of this, nearly 85,000 is in incorporated cities, giving a density in the rural districts of about 13 persons to the square mile. The population is mainly American or European, there being scattered local communities of Chinese, Japanese, and Hindoos. The latter nationalities are largely confined to truck gardening areas near the cities or to the island region. The main sources of new settlers are the North Central States, with a fair contribution from the entire northeastern fourth of the United States. The increase in population of the valley from 1900 to 1910 was about 23 per cent.

Sacramento, which is located in the southern part of the valley, is the largest city in the area and the capital of the State. It is finely located with reference to transportation, and is a distributing point for a wide surrounding territory. The main shops of the Southern Pacific Railroad and several large packing establishments, factories, and canneries are also located here. The population of Sacramento, according to the 1910 census, is 44,696.

Other rural communities and thriving towns with populations ranging from 200 to about 5,000 are located in various parts of the valley. Most parts of the valley enjoy good transportation facilities.

#### TRANSPORTATION AND MARKETS.

Steam railway transportation is provided by the main lines of the Southern Pacific Railroad with a number of branch lines traversing both sides of the valley and connecting many local points, and by the Western Pacific Railroad entering the valley at Oroville and crossing its central and southeastern portions.

In addition to these steam roads, the cities of Chico, Oroville, Marysville, Colusa, Sacramento, Woodland, Lodi, and Stockton, the latter lying just outside the area surveyed, are connected by electric lines. Another electric line runs between Sacramento, Oakland, and San Francisco.

The Sacramento and San Joaquin Rivers are plied by several lines of passenger and freight carrying boats which operate in competition with the railways. These boats also serve local island points lacking railway transportation facilities.

Farming is the chief pursuit of the people living in the rural districts. Facilities for reaching the eastern markets are also excellent.



## CLIMATE.

Sacramento Valley has a climate consisting of two distinct seasons, a wet and a dry, contrasting strongly in temperature, in precipitation, humidity, wind movement, and number of clear days. These two seasons coincide with winter and summer.

## PRECIPITATION.

The rainfall increases northward in the valley and varies from 14.5 inches at Stockton, near the southern boundary of the area, to 24.9 inches at Red Bluff, in the northern extremity. The region is thus semiarid. The rainy season usually embraces the period from November to March, inclusive, though at times it may begin in September or may continue until June. The summers are remarkably free from rainfall. The rains of winter seldom continue for longer than three or four days at a time, but in unusually wet years may last a week or more. Precipitation most often occurs as gentle showers or gentle rains interspersed with clear or foggy weather. Violent thunderstorms, hail, and cloudbursts are rare.

The rainfall is well distributed through the winter months, and owing to the gentle manner in which most of it falls it is nearly all absorbed by the soil, which is moistened to considerable depths where subsoil conditions are favorable. Long-season crops, however, frequently suffer for moisture as summer advances, because of the inability of the soil to retain sufficient moisture from the winter rains to bridge over the dry period.

The following table shows the mean monthly and annual precipitation for various stations located within the valley:

*Mean monthly and annual precipitation at various stations in the Sacramento Valley.*

Town.	Vacaville.	Woodland.	Colusa.	Willows.	Corning.	Red Bluff.
Period.....	1880-1912	1873-1909	( <sup>1</sup> )	1879-1912	1886-1912	1879-1912
January.....	6.16	3.83	3.50	3.54	4.53	4.55
February.....	3.82	2.81	2.58	2.39	3.54	3.56
March.....	4.33	2.54	2.41	2.44	3.52	3.82
April.....	1.87	1.33	1.13	1.18	1.32	1.80
May.....	1.23	0.83	0.65	0.70	0.90	1.26
June.....	0.14	0.25	0.34	0.18	0.16	0.46 ✓
July.....	T.	T.	0.02	T.	0.00	0.02 ✓
August.....	0.03	0.02	0.01	0.03	0.02	0.03 ✓
September.....	0.43	0.30	0.38	0.40	0.59	0.78
October.....	1.24	1.04	0.63	0.85	1.22	1.37
November.....	2.68	2.24	1.56	1.86	2.27	2.95
December.....	4.72	3.10	3.13	2.84	3.29	4.32
Annual.....	26.65	18.29	16.21	16.41	21.36	24.92 ✓

<sup>1</sup> The average for Colusa is taken from 1912 summary of climatological data of U. S. Weather Bureau and the period for which this is the average is not given, except that it is a broken record for 60 years.

*Mean monthly and annual precipitation at various stations in the Sacramento Valley—*  
Continued.

Town.	Chico.	Marysville.	Sacramento.	Stockton.	Oroville.
Period.....	1871-1912	1871-1912	1850-1912	1867-1912	1885-1912
January.....	4.85	3.95	3.94	3.02	5.72
February.....	3.62	3.01	2.85	2.27	4.07
March.....	3.33	3.82	2.99	2.30	4.30
April.....	1.64	1.47	1.58	1.08	1.93
May.....	0.92	0.84	0.80	0.66	1.38
June.....	0.39	0.26	0.13	0.12	0.31
July.....	0.03	T.	0.02	T.	0.02
August.....	0.02	0.01	0.01	0.01	0.02
September.....	0.60	0.37	0.24	0.22	0.76
October.....	1.27	1.14	0.83	0.68	1.52
November.....	2.54	2.15	2.00	1.50	3.26
December.....	3.93	3.37	3.89	2.71	4.46
Annual.....	23.14	20.39	19.28	14.57	27.75

The precipitation is considerably greater upon the east side of the valley than at corresponding points upon the west side. The rainfall along the west side decreases from the south to about midway to the head of the valley and then increases to Red Bluff. The east-side figures show a gradual increase from south to north throughout the valley. The rainfall is greater along the margins of the valley than in the central trough. Snow is rare, but one or more inches occasionally falls in the north end of the valley and along its margins or lower foothills. It is usually wet and seldom lies on the ground for more than a few hours. Snow is less common in the valley trough and in its southern part and rarely amounts to more than a flurry for an hour or two.

#### TEMPERATURE.

The mean annual temperature of the southern part of the valley is about 60° F. as compared with 62.5° F. for Red Bluff. The mean winter temperatures are about the same in all parts of the valley, but the mean summer temperatures show greater variations; for instance, that of Sacramento is 72.5° F., while that of Red Bluff is 82.1° F. High temperatures occur during July and August, with extremes very frequently above 100° F. at midday or in the afternoon. The nights are seldom oppressive. Very little inconvenience is experienced from high temperatures, owing mainly to the very low relative humidity, which does not often exceed 15 to 20 per cent. Heat prostrations are rare. Minimum temperatures rarely fall below 28° F. and are usually above 32° F. The high temperatures, dry atmosphere, and long summers with occasional hot winds cause excessive evaporation and unless the best possible farm practices are employed great loss of soil moisture takes place.<sup>1</sup>

<sup>1</sup> Evaporation from a free water surface at Chico in years of normal rainfall is reported to be about 63 inches. That of the Mesilla Valley, New Mexico, is 64 inches; that of Fort Collins, Colo., is 41 inches. At Tulare, Cal., it is about 70 inches, and at Pomona and Calexico it is 65 and 90 inches, respectively.

Light frosts and thin films of ice frequently occur during the winter months in the northern part of the valley, while southward the cold diminishes somewhat on account of the greater frequency of fogs.

Frosts, destructive to the more tender crops, occur as early as November at times and may continue until early in April, but they are usually confined to the winter months. Hardy vegetables, such as lettuce, turnips, radishes, onions, cabbage, cauliflower, and many other truck crops are not affected in any part of the valley by freezes during the winter months. Late spring freezes are very rare and damage to early blooming fruit seldom occurs in the areas of good air drainage. Among the crops most affected by late spring freezes are almonds, cherries, and apricots.

The average annual temperature for the valley is about the same as in the Southern California citrus belt, but the winter temperatures are lower and the summer temperatures higher in the Sacramento Valley. The valley floor, river bottoms, and depressed areas are much more subject to freezes than are the surrounding foothills and low mountain footslopes. The foothill slopes up to about 1,200 feet elevation have a minimum temperature during the winter months  $1^{\circ}$  to  $5^{\circ}$  higher than that over the flatter and lower part of the valley floor. This makes the foothills section a more favorable location for citrus-fruit orchards.

The following tables give the absolute maximum and minimum and the mean monthly and annual temperatures and the dates of killing frosts for various stations in the valley:

*Monthly and annual mean and minimum and maximum temperatures at various stations in the Sacramento Valley.*

Month.	Vacaville.			Wood- land, 1873- 1909 mean.	Colusa.			Willows.			Corning.			Red Bluff.		
	1910- 12 max.	1910- 12 min.	1880- 1912 mean.		1910- 12 max.	1910- 12 min.	1905- 1910- 12 mean.	1910- 12 max.	1910- 12 min.	1879- 1912 mean.	1910- 12 max.	1910- 12 min.	1886- 1912 mean.	Max	Min.	1879- 12 mean.
Jan.....	78	25	46.4	46.2	68	25	47.5	74	23	45.2	68	29	45.5	77	18	45.4
Feb.....	77	26	51.1	49.9	74	25	50.3	78	27	48.8	68	32	48.9	82	22	49.2
Mar.....	82	33	54.3	54.5	84	31	56.0	81	30	54.5	82	38	53.2	86	28	53.9
Apr.....	92	28	58.7	59.9	88	32	58.8	89	28	60.2	86	40	60.5	96	34	59.1
May.....	109	33	65.0	66.9	101	40	65.3	104	37	68.2	102	50	68.8	110	38	66.5
June.....	107	40	71.4	74.3	102	48	71.8	110	46	76.5	106	58	77.7	110	44	75.6
July.....	107	43	76.1	78.7	105	48	74.8	112	49	82.5	116	60	83.8	114	53	82.0
Aug.....	106	45	74.4	76.2	100	49	74.0	107	49	81.1	105	60	81.4	114	52	80.7
Sept.....	104	38	70.7	71.1	94	43	68.0	99	44	75.1	96	51	73.9	107	46	73.5
Oct.....	99	31	64.1	63.7	94	31	59.8	90	40	65.1	90	40	65.0	97	32	63.7
Nov.....	94	26	55.6	54.8	77	28	52.2	82	27	54.7	80	32	55.7	88	26	53.4
Dec.....	73	22	47.6	48.4	71	23	45.2	72	22	47.2	72	27	47.7	79	25	46.5
Annual...	109	22	61.2	62.0	105	23	60.4	112	22	63.3	116	27	63.5	114	18	62.4

*Monthly and annual mean and minimum and maximum temperatures at various stations in the Sacramento Valley—Continued.*

Month.	Chico.			Marysville.			Sacramento.			Stockton.			Oroville.		
	Max.	Min.	1871-1912 mean.	1910-12 max.	1910-12 min.	1871-1912 mean.	Max.	Min.	1850-1912 mean.	Max.	Min.	1867-1912 mean.	1910-12 max.	1910-12 min.	1885-1912 mean.
Jan. ....	78	18	46.8	76	19	48.3	72	19	45.6	68	22	46.5	75	25	47.9
Feb. ....	84	20	50.2	73	27	51.1	76	21	50.2	79	24	50.0	72	25	51.2
Mar. ....	88	25	55.5	85	31	57.2	80	29	54.2	80	31	54.5	83	33	55.7
Apr. ....	97	30	61.3	93	36	61.8	89	35	57.9	91	31	58.9	95	30	60.5
May. ....	107	33	68.2	105	39	68.5	103	39	62.9	102	40	64.1	107	33	67.1
June. ....	114	40	76.8	106	48	76.0	106	44	68.8	105	40	69.9	108	45	74.9
July. ....	117	46	83.6	107	51	78.8	110	41	72.5	110	42	72.6	112	50	81.1
Aug. ....	116	48	81.1	105	45	78.5	108	48	72.0	105	40	72.5	107	49	78.9
Sept. ....	109	40	74.1	98	44	73.6	106	43	69.0	104	45	69.0	96	45	73.3
Oct. ....	103	34	64.2	90	34	65.1	98	36	62.2	90	36	61.7	95	38	66.2
Nov. ....	90	21	53.7	79	27	56.2	81	27	53.4	84	25	53.9	81	29	56.7
Dec. ....	78	20	47.4	69	21	49.6	69	24	46.3	62	20	47.1	73	25	48.6
Annual. .	117	18	63.6	107	19	63.8	110	19	59.6	110	20	60.1	112	25	63.5

The record for Colusa is broken, and mean here shown is for portions only of four years. The maximum and minimum temperatures indicated for Vacaville, Colusa, Willows, Corning, Marysville, and Oroville are for 1910-1912 inclusive. The maximum and minimum temperatures for Red Bluff, Chico, Sacramento, and Stockton are for longer periods, but the length of the record is not indicated by the U. S. Weather Bureau reports. No data of this character are obtainable for Woodland.

*Dates of killing frosts in the Sacramento Valley.*

	Number of years of record.	Last killing frost in spring.	First killing frost in fall.	Average date of last killing frost in spring.	Average date of first killing frost in fall.	Average number of clear days annually.
Vacaville.....	3	Apr. 22	Oct. 24	Mar. 3	Nov. 13	218
Colusa.....	3	Apr. 13	Nov. 11	Mar. 5	Nov. 26	.....
Willows.....	34 (?)	Apr. 26	Nov. 11	Jan. 26	Dec. 9	233
Corning.....	2	Apr. 13	Nov. 11	Feb. 22	Dec. 1	215
Red Bluff.....	34 (?)	Apr. 12	Nov. 11	Mar. 23	Dec. 15	212
Chico.....	42 (?)	Apr. 10	Nov. 6	Mar. 27	Dec. 5	217
Marysville.....	1	Mar. 3	Nov. 25	.....	.....	267
Sacramento.....	63 (?)	Apr. 26	Nov. 11	.....	.....	212
Stockton.....	3	Feb. 25	Nov. 12	Feb. 14	Nov. 20	256
Oroville.....	3	Apr. 11	Nov. 11	Feb. 15	Dec. 10	212

**HUMIDITY.**

A low relative humidity accompanied by cloudless skies is usual through the summer season. Proceeding southward from Red Bluff, the relative humidity increases gradually and at the southern part of the valley is about 10 per cent higher than at the northern, but the humidity is also somewhat higher along the larger streams and the poorly-drained portions or intermittent lakes than on the higher plains and footslopes. The winter humidity is high on account of the rains and fogs of that season.

Heavy dew occurs during the rainy period, and this continues for a time beyond its limits. Only the low moist and swampy areas receive dew in summer and even here it disappears very early in the morning.

Fog is of frequent occurrence during the winter months, but decreases in density and frequency of occurrence northward in the valley. In the southern part it is dense during the night and morning, but frequently disappears or lifts during the day, though sometimes continuing as high fog for unbroken periods of several days. At Red Bluff an average of 9 foggy days per year is the record for 33 years, but in the southern part the average is much greater. The depressed parts of the valley are sometimes subject to light fogs at night in fall and spring, when the other portions are free from it. Fog is usually beneficial, especially in fruit growing in the valley, acting as a mantle which checks radiation from the soil, thus reducing danger of frost.

#### WINDS.

In the northern part of the valley the general air movement is from the north during the spring, fall, and winter months. Normally the summer air movement is from the south or southeast. In the south end of the valley the spring, fall, and winter winds are variable and light in character, but prevailing from the southeast and the summer winds mainly from the south. During this period ocean breezes enter the valley through the Carquinez Strait and greatly temper the interior heat.

In the Marysville region the winds of spring and fall are prevailing from the north, but are alternated with brisk winds from the south preceding rains. The summer winds are moderately cool when coming from the south or slightly southwest. The prevailing winds at Colusa are similar to those of Red Bluff.

During spring and fall the wind movement is more or less brisk for the entire valley, and pronounced south winds in winter, if prolonged, usually result in rain.

A marked climatic feature of the Sacramento Valley is the occasional strong north winds, popularly called "northers." They occur at irregular periods of several weeks and during the summer months are hot, dust laden, and oppressive. These desiccating winds, when they occur at the time of ripening grain and fruits, result in considerable damage. Considerable loss of moisture occurs from the soil during these winds. The evaporation from plants is also excessive, and vegetation generally has a drooping or wilted appearance. In fall, winter, and spring the northers are cold and disagreeable. These winds attain a velocity of 20 to 25 miles an hour, and blow for periods of about three days.

## SUMMARY.

In general the Sacramento Valley has a climate suited to a wide range of crops, including fruits. The absence of rain during the summer months allows the curing of dried fruits and hay to proceed without loss. In late fall and winter, when vegetation in the Eastern States is destroyed by cold, cultivated flowers are blooming in all parts of the Sacramento Valley and the grain fields and hillsides are green with vegetation.

## AGRICULTURE.

For many years before its acquisition by the United States, California had been occupied more or less completely by herdsmen, and although the census of 1850 shows that small beginnings had been made in the growing of wheat, corn, barley, potatoes, and fruits, the value of live stock was then many times greater than that of the crops. The live stock consisted mainly of beef cattle and sheep. There were also a considerable number of horses. Between 1850 and 1860 there was great development along many lines of agricultural production. In the order of their value in 1860, beef cattle, dairy cattle, sheep, horses, and hogs formed the live stock interests and wheat, barley, oats, potatoes, and orchard products the important agricultural products other than animal products. California in 1860, therefore, was a combined grazing and grain growing country.

A severe drought in 1862 caused great losses to the stockmen, especially to cattle men, and put a check upon the industry. This led to the growing of crops, for which mining had created an increasing demand. The first crops grown were for home use or for transportation by freighters, who formed quite an important class. The main crops were as stated above, and were grown largely on the alluvial soils. These soils were moist, water for irrigation was easily available, and the location was within easy reach of large rivers, then the principal highways for transportation.

Both climate and soils were favorable to the development of an extensive system of grain growing, and the industry was soon extended beyond the alluvial lands to the drier soils of the plains. By 1870 the production of wheat and barley had become the dominant industry of the Sacramento Valley. Production increased rapidly until it reached its maximum in 1880. Large yields were obtained, and in an exceptional case a single farmer produced nearly a million bushels in one season. From 1880 until the present time the wheat industry has gradually declined both in acreage and yields, and barley, which formerly was a minor crop, is now the leading grain crop.

With the increase in population and the demand for land, the large ranches were subdivided and the intensive crops, such as alfalfa, fruits, and truck crops, were introduced. Many large land holdings

are yet largely used for extensive grain production, but increasing land values, together with higher tax rates, tend to make the more intensive systems of agriculture necessary.

The local areas which are now highly developed show the possibilities of the greater part of the valley for special crops.

Though important, the specialized industries are so numerous that only a brief discussion of each is possible.

#### GENERAL FARM CROPS.

*Grain.*—Although the soils and climate of the Sacramento Valley are very well suited to the development of highly specialized industries, the production of dry-farmed grain is the prevailing type of agriculture. In early times wheat was the important grain crop, but constant cropping has so reduced the yields that it is being discontinued to a great extent, barley taking its place. The production of the latter has risen to 6,000,000 or 8,000,000 bushels annually. A small amount of corn is produced, but little attention is given this crop.

Oats yield very well on the moist river-bottom lands, but the crop is not well suited to the drier upland soils, except in years of high rainfall. Yields vary considerably, depending upon the season and care given in the preparation of the soil.

Wheat and barley are sowed in the fall, the exact time depending upon the moisture conditions. Some planting continues through the winter and until early spring, but much better results are obtained from early planting.

Fallowing every other year is the rule in dry farming grains, and where careful attention is given and the soil and the moisture conditions are favorable, excellent yields are obtained. From 200,000 to 300,000 tons of grain, consisting of wheat and barley, are cut for hay each year, the amount depending largely upon the demand for hay and upon the rainfall. The high value of land, where irrigation is available, makes the growing of small grains inadvisable, alfalfa and other more valuable crops replacing them.

*Alfalfa.*—With irrigation, alfalfa becomes the important general farming crop. Even lands which have been reduced in productivity by grain growing give good returns with alfalfa. Five crops are usually cut each year and with good care total yields of 6 to 8 tons per acre are obtained. The average yield for the entire valley, however, is about 3.5 tons per acre yearly. This comparatively low average is due mainly to the utilization of soils poorly suited to alfalfa, to insufficient irrigation, and to lack of care of the fields.

For best results, soils free from hardpan to a depth of 6 feet or more, or those under which the water table lies at that depth or deeper,

give the best yields. If the land has good slope and ample water is available, fair yields may be obtained on shallower soils. The life of the plants upon the areas of shallow soil, however, is seldom more than 4 or 5 years. In the lowland sections along the larger streams and in the island district south and southwest of Sacramento excellent yields of alfalfa are obtained for about 5 years where the water table is not more than 2.5 to 3 feet below the surface, providing this water level does not fluctuate much and the soil is free from alkali.

Alfalfa production is increasing greatly at the present time. The average price per ton is reported to be a little less than \$10.

The soils best suited to this crop are loams, fine sandy loams, silty clay loams, clay loams, and clays, in the order named. The heavier soils have a tendency to shorten the life of the plant. Good drainage and freedom from alkali are important. With better methods, a more uniform system of irrigation and the selection of the most favorable soils, average yields can be increased to 7 or 8 tons per acre.

Many varieties of alfalfa have been tested in the valley. The Chilean alfalfa, the first introduction, appears to be best suited to the soils and climate. Where the moisture supply is scant, the Turkestan varieties may prove best, and for young orchards or short period plantings, Arabian alfalfa has proved very satisfactory.

*Rice.*—The production of rice has only recently been introduced in the Sacramento Valley, though the success already achieved with this crop indicates that it may become very important. Because of favorable soil conditions, Butte County leads in rice culture. Until recently rice was confined to a small acreage, mainly as experimental plots. About 5,000 acres were planted in 1913 and preparations have been made for a greatly increased acreage. The average yield for 1913 was about 4,000 pounds per acre, which sold for about 2 cents a pound. After threshing, the straw is shipped to Antioch for paper making.

There is an extensive area of lowland north of the Marysville Buttes that seems to be suited to rice culture, the soil being the Stockton clay adobe. The level surface features, the high lime and humus content, the heavy, compact subsoil, and calcareous hardpan or substratum, which prevents water from escaping by percolation during necessary flooding, are conditions which favor the growing of this crop, and these conditions are well developed in this soil.

The Honduras and the Japanese rice are the varieties grown. The Japanese has been most widely planted and has done well.

A system of crop rotation will probably be necessary for continued success with rice culture on this type of soil in order to maintain its physical conditions and productiveness.

A rice mill is now under construction at Biggs for the handling of the crop. This will aid much in establishing rice growing on a permanent basis.



## NUT CROPS.

*Almonds.*—Almonds were first introduced into California from countries bordering the Mediterranean Sea, but did not prove successful. New types were later obtained that were better suited to California soil and climate, and since their introduction the industry has reached a considerable degree of development. The tree seems to be quite sensitive to soil conditions. It gives best returns upon the thoroughly well-drained soils, either those of light texture or the well-granulated and well-drained heavier types. Low flat areas or basinlike depressions, especially if the soils are heavy and damp, do not seem to give good yields. The almond blooms early, and for this reason plantings are usually confined to elevations or slopes where unseasonable frosts are less likely to occur.

The varieties most grown on the soils of the Sacramento Valley are IXL, Ne Plus Ultra, Nonpareil, and Texas Prolific. These are leading commercial paper-shell sorts that bear regularly. Experience has proved that better fertilization of the blossoms and consequently better yields are obtained if the different varieties are planted in alternate rows.

Trees bear at about 3 years from planting and continue with increased yields until 15 to 20 years old. Yields of a ton of nuts per acre are not uncommon. The price ranges from 10 cents to 20 cents per pound.

Most of the almonds are grown without irrigation, the rainfall being relied upon, with good tillage, to mature crops. The 1910 census shows that during that year 18,500,000 pounds of almonds were imported into this country, while during the same period only 8,000,000 pounds were produced in California. Of the areas suitable for almond culture in the United States, California seems to be most favorably situated. There seems to be considerable land suitable for this crop in the valley, and with the existing demand there is a promising outlook for those desiring to enter this industry.

There are about 900,000 bearing and 500,000 nonbearing trees in the valley.<sup>1</sup> Early returns were uncertain, but later experience has taught that successful culture can be attained under favorable conditions.

*Walnuts.*—The walnut ranks first among the nuts grown in California. Under favorable conditions the trees attain large size. The tree prefers a deep, light loam or sandy loam, and even does well on loamy sands. It bears regularly and with proper care yields heavily. Little trouble from pests occurs and only a small amount of pruning is necessary. There are about 20,000 bearing and about 50,000 young, nonbearing trees in the Sacramento Valley. Most of the

<sup>1</sup> The statements concerning plantings of the various nuts and fruits discussed in this report are taken from the reports of the State horticulturist.

nuts grown to date are seedlings of foreign varieties, but soft-shelled varieties are now being grafted on native black walnut stock, bearing age being more quickly reached in this manner, and the tree made more resistant to sunburn.

Trees for commercial planting are set 40 to 50 feet apart, and mixed plantings are used to insure a more complete fertilization of the flowers. Hoed crops are grown between the trees until the latter come into bearing. With care in the selection of soils, the production of this nut appears to have a promising future.

*Miscellaneous nuts.*—A few specimens of the butternut, chestnut, and pecan occur within the valley, but the culture of these while somewhat promising is not of any commercial importance at present. The two former thrive best in the moist soils of the river bottoms. The butternut can be grown for home use. Commercial planting of the chestnut and pecan is not advisable until the more promising varieties shall have been determined by field tests.

#### FRUIT CROPS.

*Citrus fruits.*—The citrus industry is rapidly extending into the Sacramento Valley and excellent results have been obtained in those sections where soil and climatic conditions are favorable. There are about 200,000 bearing and 60,000 nonbearing orange trees, and about 6,000 bearing and 700,000 nonbearing lemon trees in the valley, the latter being largely in a single orchard.

The citrus industry is confined mainly to the lower foothills, where the slope tends to protect the trees from winter freezing and where the soils are thoroughly drained. Most of the plantings have been made on loams, heavy sandy loams, and light clay loams. The trees usually make a satisfactory growth. The fruit matures in time for the Thanksgiving and Christmas trade. Practically all of it is gathered before any danger from frost occurs. On account of the danger from occasional freezes over the valley floor, this industry will likely reach its best development along the foothills of the Sierras and the Coast Range. There is a large acreage on the low hills along the borders of the Sacramento Valley which can be utilized for citrus-fruit culture, when irrigation is provided. The Navel is the principal orange grown.

*Peaches.*—Peach culture ranks as one of the most important industries in the valley. There are about 2,000,000 bearing and 1,000,000 nonbearing trees and the industry is well distributed over the valley.

The sandy loams, loams, and loamy sands, in the order named, of many of the soil series encountered in the Sacramento Valley are well adapted to the growing of this fruit, and moderate to high yields are obtained when proper varieties have been planted and good care

is given the orchards. Some of the fruit is placed on the market fresh, some is sold to near-by canneries, and large quantities are dried.

Peach trees come into bearing about 3 years after planting and with good care continue to produce well for 12 or 15 years. Elberta, Early and Late Crawford, and Early Imperial for freestones, and George Late Cling, Phillip Cling, Tuscan Cling, McKevitt Cling, and Orange Cling are among the leading varieties grown.

The late blooming of this fruit lessens the danger from spring freezes, but considerable pruning is necessary and some trouble from pests occurs, though these can be controlled by modern methods.

In the more favorable locations, where the soils are retentive of moisture, peaches are grown with considerable success without irrigation, but on shallower, more droughty soils, irrigation is an important item in the production of paying crops.

With many competing regions nearer to the large eastern markets, and the perishable nature of this fruit, it is necessary to dispose of most of the fresh peaches locally. The canned product, however, has good flavor and is attractive. The facilities for drying the fruit also are good and the product is of high quality.

*Cherries.*—Most of the cherries grown are of the sweet varieties. There are about 160,000 bearing and 60,000 nonbearing trees in the local orchards, which are confined to the margins of the valleys, where the soils are deep, well drained, friable, and protected from freezing and cold winds. Loams, fine sandy loams, sandy loams, and light silty clay loams and light, well-granulated, clay loams of the soil series encountered are well suited to the growing of this fruit where local climatic conditions are favorable.

The Bing, Early Purple Guigne, the Black Republican, Nonpareil, Tartarian, Royal Ann, and Richmond are the most generally approved varieties. The May Duke, Morella, Advance, Centennial, Chapman, and Cleveland are also grown.

*Olives.*—Olive culture has been an industry in the valley for many years. It has not, however, been on a stable basis until recently, owing to lack of knowledge of pickling and oil making, to poor methods of marketing, and to lack of care of orchards. The hardness of the olive tree has led to a belief that little care is necessary beyond setting out the trees. As a result, many orchards have been neglected and a small amount of very inferior fruit is obtained. Recently the methods of handling olives have improved greatly and the industry has been placed on a firmer basis.

There are about 300,000 bearing and 80,000 non-bearing trees in the Sacramento Valley. Olives are now in great demand and farmers have no difficulty in contracting their crops several years in advance. With good care, yields of 1 to 3 tons per acre are obtained.

The Mission and Manzanillo are the main varieties grown, but other larger and more attractive varieties have recently been receiving attention and are proving well suited to the local soils and climate. The larger varieties are in great demand and bring handsome prices. Ripe olives are used both for pickling and for oil making, the green fruit being used for pickling alone.

The olive does moderately well on quite a wide range of soils. It thrives best, however, on loams, gravelly loams, sandy loams, fine sandy loams, and light clay loams in the order named. Olive soils should be free from standing water, deep and friable, not too high in humus, and not subject to periodic overflow. The olive is one of the most drought resistant of trees, but for best results requires irrigation to avoid tendencies toward light and irregular bearing. Low-lying areas, basinlike depressions, and cold, windy exposures seem to be unfavorable. Olives come into bearing at 4 to 5 years and at 7 years from 12 to 20 quarts of fruit per tree may be expected. The trees are long lived and if properly cared for should produce good crops for more than a quarter of a century.

*Figs.*—Little attention is given to fig production, this fruit being grown mainly as border trees along roadsides. Some Smyrna figs have been planted in recent years, but the trees are usually not yet in bearing. All well-drained soils free from alkali and of good depth seem to produce vigorous, heavy-bearing trees.

The Mission or California Black, one of the Adriatic figs, is most extensively grown, although the White Adriatic is also planted. Fig trees grow rapidly, bear heavily, and the fruit is suited to a wide range in use, including drying, canning, preserving, shipping as fresh fruit, and for home use. Much of the fruit is allowed to drop from the trees and rot. Only a small fraction of the figs consumed in the United States are produced within its borders. With improved distribution, handling, and marketing, and the wide range of soils in the Sacramento Valley well adapted to the growing of this fruit, the industry should be capable of extension.

The trees are long lived and little fruit is produced until they are 4 years old. Little trouble from insect pests or diseases has occurred. Considerable pruning is necessary on account of the tendency to produce dense top.

*Apricots.*—This fruit, like the plum, is adapted to a wide range of soils. There are 500,000 bearing and about 40,000 non-bearing trees in the valley. These are confined chiefly to Solano, Yolo, and San Joaquin Counties, although the fruit is grown over the entire valley.

Apricots do well on the soils used for plums and prunes, but low areas are avoided because of the early blooming of this tree. The fruit is in demand by eastern markets, at local canneries, and for drying.

The Blenheim, Moorpark, Royal, Tilton, Routier's Peach, and some others are the varieties in greatest favor.

*Plums and prunes.*—Plums and prunes are important fruits. There are about 700,000 bearing and 200,000 nonbearing plum trees and about the same number of prune trees distributed in favorable locations throughout the valley.

These fruits require the same soils and treatment. The prune is characterized by its sweet, firm flesh, which dries and cures. The plum does not cure like the prune and must be used as fresh fruit or canned.

The sandy loams, loams, and clay loams of the various soil series, where deep, friable, well drained, and free from alkali, are largely used for the growing of these fruits.

Plum trees are subject to sunscald, but low heading prevents this injury to a great extent. The varieties of plums most extensively grown are the Prune d'Agen, Burbank, Climax, Clyman, Diamond, and Purple Duana and of prunes, the German, Golden, Kelsey, Peach, Pond, and a number of others.

The cost of bringing an orchard into bearing is about the same as in the case of peaches, but the period of productiveness of plums and prunes is, perhaps, somewhat greater.

*Grapes.*—Grape growing is an important industry in the Sacramento Valley. It has developed rapidly and extended to many favorable districts. Of the varieties used for wine making, there are about 20,000,000 bearing and 3,000,000 nonbearing vines; of the table varieties about 15,000,000 bearing and 4,000,000 nonbearing vines; and of the raisin varieties about 2,000,000 bearing and 400,000 nonbearing vines.

The soils and climate of the Sacramento Valley have proved very favorable for the production of table and wine grapes, but less favorable for the production of raisin grapes than those of the San Joaquin Valley. About four-fifths of the wine and table grapes and one-half of the raisin grapes of the valley are produced in San Joaquin and Sacramento Counties, with the rest well distributed over the valley.

The varieties used mainly as table grapes are Tokay, Black Cornichon, Thompson Seedless, Emperor, Malaga, Rose of Peru, Sweetwater, and a few others of less commercial importance. Experience has demonstrated that the best returns are realized from the above-named varieties. For wine making, Zinfandel, Mission, Grenache, Alicante Bouschet, Palomino, and Burger are the leading varieties, and for raisin making, the Muscat and Thompson Seedless are the most popular.

All these varieties do well in the area, but better in some parts than in others, and there is no doubt the type of soil as well as climate is an important factor influencing the flavor and color of the fruit.

Most of the grapes are grown without irrigation, but the use of water is increasing. In years of normal or high rainfall, little irrigation is necessary for most varieties, if thorough cultivation is given the vines, but in dry years one or two applications of water will greatly increase the yields. Little or no fertilizer is used and clean culture is practiced. Yields of 3 to 8 tons per acre are obtained.

Table grapes are packed in boxes for shipment and are sent east in car lots. For raisin making, the grapes are laid on wooden trays or sheets of paper and dried in the sun. Wine grapes are often loaded loose on cars and transported in this manner to the winery.

The annual cost of producing table grapes is from \$20 to \$35 per acre and somewhat less for the raisin and winemaking varieties. The vines begin bearing about 3 years after setting, and with good care produce profitable returns for 10 or 15 years.

*Pears.*—Pear culture has been an important industry for many years. Diseases, such as blight, with inefficient methods of cultivation, and marketing systems, however, in recent years curtailed the development of this industry. These conditions have frequently resulted in the abandonment of orchards. There are about 600,000 bearing and about 200,000 nonbearing trees in the valley.

Pears are grown on a wide range of soils where drainage is good and alkali absent. Pear culture has been most successful where the soil is at least  $3\frac{1}{2}$  feet in depth and underlain by open subsoils to 6 feet or more. Pears will stand as much alkali as any of the tree fruits, but lands even slightly affected should be avoided unless underdrains have been installed. Hoed crops are grown with profit between the rows until the trees come into bearing.

The Bartlett is the most popular variety, is marketed readily as fresh fruit, is unexcelled for canning, and valuable for drying. Many other varieties are grown with success, but they more frequently meet competition with the products of other sections of the country. With improved methods of distribution and handling, there is yet room for expansion in this industry.

The market is usually good and the quality of the fruit produced is of the best. The cost of bringing an orchard into bearing is about the same as in the case of peaches.

*Melons.*—Melons, including cantaloupes, muskmelons, watermelons, and casabas, thrive on the light loams and sandy types of practically all the soil series in the valley, where drainage and alkali conditions are favorable. Little attention has been given to markets outside of the State and the greater part of the melons are grown on soils well located near home markets.

*Small and miscellaneous fruits.*—The important cane and brush fruits, which do well on nearly all the soils of the valley, except on the heavy clays and where alkali accumulations interfere, are the

loganberry, blackberry, dewberry, raspberry, currant, and gooseberry. The demand for these fruits is largely confined to home markets and there is little encouragement to produce them on a more extensive scale. Where irrigation is possible, the very shallow hardpan soils and other soils unfavorable for the tree fruits may be used for these small fruits.

Besides the fruits stated, large yields of strawberries are obtained, the local markets being supplied practically throughout the entire year by the valley growers. Plantings of this fruit are confined mainly to the well-drained sandy loams and loams of practically all the soil series developed near the larger towns.

The nectarine, Japanese persimmon, pomegranate, loquat, and some of the newer Oriental and European introductions give promise on well selected soils of the Sacramento Valley. Further observation and experiment will be necessary before they can be recommended for extensive planting.

#### TRUCK CROPS.

Many vegetables give heavy yields on the low, moist light types of soil. The hardy vegetables are produced the year round and one crop follows another in close succession. In many instances three or more crops are produced on the same land in one year. Moderate to heavy applications of fertilizers are generally made in growing the truck crops. Trucking is confined chiefly to areas near the large cities and towns and most of it is done by Chinese and Japanese gardeners.

Large quantities of celery and onions are produced on the Muck and Peat soils and to some extent on the lighter textured, deep, friable soils along stream bottoms. Heavy yields of these crops are obtained on the Muck and Peat lands. In some cases several trainloads of each crop are produced by a single grower.

Potatoes are also an important crop on the soils mentioned above. Continuous growing of these crops on the same soil has recently given way to a system of rotation.

*Asparagus*.—Asparagus is adapted to a considerable range of soil textures but the successful growing of this vegetable for commercial purposes is confined mainly to the soils of the Columbia series, the Sacramento clay loams, and Muck and Peat in the island region of the southern part of the area surveyed. Other moist river-bottom soils in the valley and deep upland types, where supplied with irrigation, are also well suited to the growing of this crop. The development of the industry on a commercial scale, however, has been confined mainly to the Muck and Peat lands. Asparagus is sold to some extent fresh, but is more extensively utilized for canning.

On the Muck and Peat soils the rows are usually run 9 to 10 feet apart, but on other soils 5 to 7 feet is the common distance. Close

planting generally shortens the life of the bed. Some cultivated crop such as beans, potatoes, or onions is often planted between the rows until cutting begins, usually the third year, but after this the entire use of the soil is given to the bed. The Muck and Peat soils, which contain moderate to large quantities of inorganic matter, seem to be best suited to this crop. The life of the bed varies greatly, but with good care should be 12 years or more. Little fertilizer is used. Yields of 7,000 to 8,000 pounds per acre are often obtained on the best lands, with an average of about 5,000 pounds per acre for the asparagus growing districts as a whole. Several large canneries handle this crop and the growers are reasonably certain of moderate to good prices. Asparagus is often grown on a share basis by Chinese and Japanese tenants. The Conover Colossal appears to be the most desirable canning variety and the Palmetto the best variety for marketing fresh. Several other promising varieties are grown.

#### ANIMAL HUSBANDRY.

*Dairying.*—The open winters, excellent markets, good transportation facilities, the large amounts of grain grown, and the heavy yields of alfalfa under irrigation, make dairying a very attractive and profitable industry in the Sacramento Valley. This business has grown rapidly in recent years and much attention is now being given to bettering dairy breeds. There are about 70,000 dairy cows in the valley, and large amounts of cream and milk are shipped to the cities about San Francisco Bay daily. Wherever dairying is carried on, the tendency is to increase greatly the productiveness of farms, which have a generally prosperous appearance. The outlook for those interested in dairying is very promising. The returns from this source at present amount to more than \$2,000,000 annually.

*Sheep.*—Mutton and wool are among the leading products of the valley. There are more than 1,000,000 sheep in the valley and near-by foothills regions. Many sheep are kept in the hills during summer and brought to the valley to graze over fields and on the extensive untilled areas of land in winter. They are owned mainly by men controlling large tracts of land. The income from this industry is large.

*Hogs.*—The yearly output of hogs is about 150,000. The industry is developing rapidly and holds a very important place in the agriculture of the valley. Experience of farmers shows that grain fed to hogs will bring more than twice the price that it will bring if sold on the market as grain. The excellent opportunities for the production of alfalfa in the Sacramento Valley and its high value as a feed for hogs, together with the constantly increasing demand for pork, favor the growth of the industry.



*Bees.*—There are about 10,000 colonies of bees located in various parts of the valley. The comparatively little effort required to handle them in this mild climate, the abundant pasturage, high quality of honey, and stable market demands make the industry attractive. Bee keeping is very well suited to the small farmer.

*Poultry.*—The production of poultry is closely associated with dairying and hog raising in the Sacramento Valley. There are nearly a million fowls in the valley, most of which total is made up of small flocks found upon the average farm. A number of large poultry plants are located in various places, which are said to bring satisfactory incomes to the owners.

Turkeys are raised in large numbers on many of the ranches. The cost of raising under existing conditions is low, little care being required after the birds are large enough to forage. They are utilized to excellent advantage in grainfields too poor to be harvested.

Poultry keeping is an excellent subsidiary industry for the small farmer, and it is also succeeding where followed as a specialty. The returns from the sale of poultry products amount to more than \$1,000,000 annually.

*Horses.*—The conditions making dairying successful in the valley should also encourage farmers to produce more horses and mules. The production of such animals is not equal to the demand and shipments are brought in from other States.

#### SOILS.

The great Interior Valley of California was first an arm of the sea, then a lake, and finally, after variations in elevation, a drained area as at present. This great valleylike depression has long been the resting place for accumulating sediments of varied character washed from the adjacent mountains. The present valley floor and slopes are largely occupied by rather recent deposits, however, which have buried the older, and it is mainly along the edges of this survey that the older rocks and upturned sediments are found.

The accumulated sediments in the Sacramento Valley are of unknown depth. Several borings of over 2,000 feet have failed to penetrate anything but unconsolidated materials. Geologically speaking, all the deposits are of very recent age, but the activities of modern streams have been sufficient to erode, alter, and redeposit the materials of the older formations, with important additions from the lateral ranges, until much of the surface of the valley is occupied by recent alluvial and alluvial-fan deposits.

The soils of the Sacramento Valley are derived from or consist of four classes of material. They are (a) residual material, (b) old valley-filling material, (c) recent alluvial-fan and alluvial material, and (d)

wind-deposited material. The soils as they exist at present are largely the product of the weathering of the older of these materials, while the very recently deposited material has been changed in place very little. The soils from the consolidated rocks are the product of weathering in place. These are often deeply and thoroughly weathered. The soils derived from the older sedimentary or alluvial deposits of the valley are well weathered as a rule. There are, however, unweathered or feebly weathered soils derived from residual material, as well as from the older valley deposits.

From these various kinds of soil materials, a number of soil series, each represented by one or more soil types, have been derived.

A soil series consists of a group of soils having similar characteristics of color, of subsoil or substratum, of parent material, and of mode of formation, but differing in texture, that is, in the proportion of the particles of differing sizes of which each type is composed.

The soil type is thus the usual unit of classification in soil mapping, the types being represented upon the soil map as, for instance, sand, sandy loam, or clay loam, with the appropriate series name. In the survey covered by this report, however, which is of a general or reconnaissance nature, the soils in certain cases are indicated upon the map as undifferentiated types under the series head, or as groups of two or more types, differentiation of which in the field was not deemed essential for the purposes of the survey. In such cases the grouping has been done with a view to combining soils most alike in their main characteristics.

The area embraced by this survey includes the Colusa, Marysville, Woodland, and Red Bluff and portions of the Sacramento and Stockton areas previously surveyed by the Bureau of Soils.<sup>1</sup> In the present survey the classification used in these earlier reports has been modified to some extent, and in some cases soils previously recognized and mapped have not been identified as soil types. It now appears that in the most of these the differences are of minor character and the soils are now regarded as phases of some other type rather than distinct soils. In many cases the true relationship of the soils was not observed in the detailed surveys, but became apparent in the study of the series relationship upon the broader reconnaissance scale covering the entire valley.

#### RESIDUAL MATERIAL.

The group of residual soils is derived from the disintegration and weathering in place of consolidated rocks. The soils vary widely in origin, color, texture, and structure. They occur largely along the

<sup>1</sup> For detailed reports on the soils of these areas see: For Stockton area, *Field Operations of the Bureau of Soils*, 1905; Colusa County, Marysville area, and Woodland area, *Ibid.*, 1909; Red Bluff area, *Ibid.*, 1910.

margins of the area, occupying the lower foothill slopes which mark the beginning of much greater extents of mountainous regions covered by soils of the same character. The parent rocks are various. Seven series of soils are of this group.

#### OLD VALLEY-FILLING MATERIAL.

The soils formed from old valley-filling deposits represent material occurring as remnants of older sedimentary deposits reduced to smaller area through erosion. They usually occupy positions intermediate in elevation between the more elevated residual group and the lower lying recent alluvial soils. The original deposits, derived from a wide variety of rocks, have subsequently been much changed and the soils now differ rather widely in some essentials. These soils are usually distinct from those of the residual and alluvial classes, but in their lowest positions merge with the latter group. They occupy positions along the margin of the valley or cover upland plains constituting the upper valley slopes. Ten series are represented in this group.

#### ALLUVIAL AND RECENT ALLUVIAL-FAN DEPOSITS.

The recent soils of the alluvial and alluvial-fan group are derived from the deposits laid down by both intermittent and perennial streams, either as alluvial bottoms along streams or as alluvial fans over the valley slopes and in regions of poor drainage within the valley trough. They are now in process of formation. These deposits give a wide variety of soils upon which the greater part of the agricultural development of the valley has taken place. They are included in 16 series.

#### WIND-LAID MATERIAL.

The soils of the wind-laid group are of small extent in this survey. They consist mainly of river sands drifted landward by winds. They are represented by one type of the Oakley series.

#### MISCELLANEOUS MATERIALS.

Besides the four general groups already discussed a number of soils have been brought together under the head "miscellaneous materials." These include the cumulous soils, Muck and Peat, classed as miscellaneous because differing so markedly from the great majority of soils; and Rough stony land, Tailings, Riverwash, and Tidal marsh, unimportant nonagricultural soils.

In the following table, giving the area of each soil type or group, the soils are arranged in four groups corresponding to the four classes of materials from one or another of which they have severally been

derived, and in a miscellaneous group including types that could not be placed in either of the other four:

*Classification and area of the different soils mapped in this survey.*

Soil groups and types.	Total area of type.	Proportion of total area.	Soil groups and types.	Total area of type.	Proportion of total area.
Soils from residual material:			Soils from old valley-filling material—Continued.		
Sierra series—			Montezuma series—		
Sierra sandy loams and loam <sup>1</sup> .....	Acres. 6,848	Per cent. .2	Montezuma clay adobe....	Acres. 57,152	Per cent. 1.4
Aiken series—			Alamo series—		
Aiken stony soils (undifferentiated).....	26,176	0.6	Alamo clay adobe.....	14,144	.4
Aiken loams.....	41,856	1.1	Soils from alluvial and recent alluvial-fan deposits:		
Altamont series—			Honcut series—		
Altamont soils (undifferentiated).....	71,296	1.8	Honcut loams.....	22,848	.6
Mariposa series—			Vina series—		
Mariposa silt loam.....	896	.1	Vina fine sandy loam.....	19,200	.5
Arnold series—			Vina loams.....	22,848	.6
Arnold sandy loam.....	18,752	.5	Vina gravelly loams, shallow phase.....	4,672	.1
Arnold loams, shallow phase.....	28,800	.7	Vina clay loams.....	53,952	1.3
Butte series—			Vina clay adobe.....	24,896	.6
Butte stony soils (undifferentiated).....	13,632	.3	Willows series—		
Diablo series—			Willows fine sandy loam..	1,984	.1
Diablo clay adobe.....	3,200	.1	Willows loams.....	95,552	2.4
Soils from old valley-filling material:			Willows clay.....	51,200	1.3
Redding series—			Willows clay adobe.....	138,944	3.5
Redding gravelly loams..	186,176	4.6	Madera series—		
San Joaquin series—			Madera loams.....	122,048	3.0
San Joaquin loams.....	341,824	8.5	Madera clay loams.....	29,696	.7
San Joaquin and Arnold loams (undifferentiated)	56,192	1.4	Madera and Gridley loams (undifferentiated).....	94,144	2.3
Corning series			Madera and Gridley clay loams (undifferentiated)	46,144	1.1
Corning gravelly loam....	81,792	2.0	Madera and Gridley clay adobes (undifferentiated).....	23,744	.6
Kimball series—			Yolo series—		
Kimball loam.....	29,248	.7	Yolo fine sandy loam.....	11,712	.3
Tuscan series—			Yolo loams.....	45,248	1.1
Tuscan stony loams.....	93,568	2.3	Yolo clay loam and clays..	90,496	2.3
Gridley series—			Hanford series—		
Gridley loams.....	36,544	.9	Hanford fine sandy loam..	75,840	1.9
Antioch series—			Solano series—		
Antioch loam and clay loam.....	13,248	.3	Solano loam and clay loam	36,096	.9
Antioch and Montezuma soils (undifferentiated)...	74,496	1.9	Solano clays.....	15,552	.4
Fresno series—			Tehama series—		
Fresno loams.....	16,896	.4	Tehama loams.....	173,248	4.3
			Tehama gravelly loams...	28,048	.6
			Tehama clay loams and clay.....	45,248	1.1

<sup>1</sup> Includes areas of Siskiyou, Holland, and Sheridan soils, undifferentiated.

*Classification and area of the different soils mapped in this survey—Continued.*

Soil groups and types.	Total area of type.	Proportion of total area.	Soil groups and types.	Total area of type.	Proportion of total area.
Soils from alluvial and recent alluvial-fan deposits—Con.			Soil from alluvial and recent alluvial-fan deposits—Con.		
Columbia series—			Laguna series—Continued.	<i>Acres.</i>	<i>Per cent.</i>
Columbia fine sandy loam and sands.....	114,240	2.9	Laguna clay adobe.....	704	0.1
Columbia silt loams.....	300,096	7.5	Kirkwood series—		
Sacramento series -			Kirkwood clay adobe.....	7,744	.2
Sacramento clay loams....	74,944	1.9	Elder series—		
Sacramento clays.....	354,240	8.8	Elder sands and gravelly sandy loams.....	5,952	.1
Capay series—			Elder gravelly loams.....	9,152	.2
Capay clays.....	53,952	1.3	Elder silt loams.....	17,344	.4
Capay and Yolo clay loams and clays (undifferentiated).....	81,280	2.0	Wind-laid material:		
Sutter series—			Oakley series—		
Sutter loams.....	19,200	.5	Oakley sand.....	2,752	.1
Sutter clay loam adobe and clay.....	2,240	.1	Miscellaneous materials:		
Stockton series --			Muck and Peat.....	187,520	4.7
Stockton clay loams.....	12,352	.3	Riverwash.....	12,800	.3
Stockton clay adobe.....	186,112	4.6	Rough stony land.....	61,248	1.5
Laguna series—			Tailings.....	13,248	.3
Laguna loam and clay loam.....	12,352	.3	Tidal marsh.....	1,792	.1
			Total.....	4,015,360	.....

## SOILS FROM RESIDUAL MATERIAL.

## SIERRA SERIES.

The soils of the Sierra series are prevailingly light red or grayish red, but as recognized, in this area, light-red or reddish-brown colors prevail. They are underlain by red compact subsoils, which in turn rest at varying depths upon the parent rocks. The soils are frequently shallow and carry angular to subangular fragments with abundant outcrops, and include rough, rocky areas unsuitable for agriculture. They are of residual origin, being derived from the weathering of granitic rocks, and in this area granodiorite is the most common rock. The soils of this series occupy rolling foothill areas of small extent along the eastern edge of the survey. They are generally well drained. The series includes large areas of valuable fruit and grazing lands east of this area along the western slope and base of the Sierra Nevada Mountains, and is often associated with the Aiken series.

SIERRA SANDY LOAMS AND LOAM.<sup>1</sup>

*Description.*—The Sierra sandy loams and loam include the coarse sandy loam, sandy loam, and loam of the Sierra series.

The Sierra coarse sandy loam is the most extensive soil of this group. In this area it consists of a light-red, or brownish-red, friable coarse sandy loam, which extends to a depth of 12 to 30 inches. The soil contains coarse particles of angular quartz in quantities sufficient to give the surface a lighter appearance than is warranted by the color of the fine soil material. While the soil is sometimes very shallow, it is in places several feet in depth. Typically it passes into a layer of red, plastic sandy clay material, which in turn grades into less disintegrated granodiorite rock material, and, at a depth ranging from 1 foot to several feet, the unaltered rock is encountered. Both soil and subsoil are absorptive and retentive of rainfall, and good tillage conditions prevail.

The Sierra sandy loam is a minor type in the group, and does not vary in any general characteristic, other than texture, from the coarse sandy loam member.

The Sierra loam consists of a light-red, rather sticky loam, grading into redder clay loams or clays at depths of 12 to 24 inches or more. It does not carry so much angular quartzose material as the other members. It is generally associated with small areas of flatter topography within the group. Like the sandy loam, it is inextensive in this survey.

It is recognized that in classifying these soils on the basis of color, this group includes small undifferentiated bodies of the soils previously recognized in other surveys as the Holland, Siskiyou, and Sheridan series. The material, as a whole, however, is included with the Sierra series as being the predominant material to the eastward, of which the group in question is the lower extension within this area.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Sierra coarse sandy loam type:

*Mechanical analyses of Sierra coarse sandy loam.*

Number.	Descrip- tion.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
12036, 12039.....	Soil.....	13.0	23.5	10.1	17.6	7.4	15.1	12.8
12037, 12040.....	Subsoil.....	11.6	21.9	9.6	15.9	7.0	14.2	19.2

*Location.*—The soils of this group are rather inextensive in this survey, occurring as several bodies along its eastern edge east and north-

<sup>1</sup>Includes areas of Siskiyou, Holland, and Sheridan soils, undifferentiated.



FIG. 2.—SHOWING REGIONAL TOPOGRAPHY IN FAIROAKS CITRUS BELT.

[The soils belong in the San Joaquin and Arnold series.]





ward from Lincoln. They are associated with the Aiken loams and merge on their valleyward margin with the old alluvial deposits giving rise to the Redding, San Joaquin, and associated series.

*Topography and drainage.*—The soils have a rolling, hilly or dissected surface, with, in places, protruding masses of outcropping parent granodiorite. Drainage is ample to excessive. As a rule the slopes are not too steep for cultivation, but fields are sometimes patchy and irregular in outline owing to rock outcrops and the minor drainage ways.

*Utilization.*—The soil types of the group were originally forested. The native vegetation consisted mainly of oak and a brushy undergrowth. They are now extensively utilized mainly for the production of grain and grain hay. There are a few orchards, and these indicate the adaptability of the soils to various fruit crops. Some mature trees have been grown without irrigation, but usually the soils require irrigation in order to be used successfully for the production of intensive crops. The same soils east of the area surveyed produces profitable yields of cherries, pears, grapes, plums, peaches, apricots, figs, berries, and other staple fruit crops. Citrus fruits are likewise grown where frost conditions are favorable.

#### AIKEN SERIES.

The soils of the Aiken series are typically red, yellowish-red, or dark red in color and in this area include phases with shades of dark reddish-brown. The series as occurring in this area is predominantly of shallow, stony character with little development of the red color in the subsoils usually accompanying the deeper weathered material and is in agricultural importance inferior to the stony soils of the Aiken series as previously encountered in various surveys. The soils are typically well drained and some phases encountered in this survey are inclined to be droughty. They occupy foothill slopes or plateaulike uplands, the surface varying from gently sloping to steep, rough, and broken, with frequent rock outcrops. The soils of the series are of residual origin and derived mainly from basic igneous and metamorphosed igneous rocks, including basaltic and andesitic material, diabase, amphibolite, serpentine, etc. In this survey much of the material encountered is derived from volcanic tuffs and breccias. The series is very extensive throughout northern California. In this area it is mainly non-agricultural. Where topography and depth are favorable, these soils are suited, with irrigation, to a wide range of crops. The subsoils usually have a somewhat deeper red color and a slightly heavier texture than the soils.

## AIKEN STONY SOILS (UNDIFFERENTIATED).

*Description.*—This soil group, while subject to some variation in texture, is predominantly a loam, of gritty, stony, and very shallow character. The shallow mantle of soil material ranges in places to a clay loam or sandy loam, but such variations in texture have little effect upon the general value of the soil, in view of the more important influences of slight depth and high stone content. The thin, patchy soil covering ranges in color from reddish brown, or brown to red or dark red, the latter color being present only where the soil is deepest. A yellowish-gray or yellowish-brown phase usually occurs where the soil is thinnest and erosion most active. The soil material rarely attains a depth of 12 inches, often does not average more than 6 inches over large areas, and on many included slopes and ridges is entirely absent.

The soils of this group are in the area surveyed nonagricultural. They are too shallow for cultivation, are not retentive of soil moisture, and are characterized by the presence of large quantities of andesite boulders and angular rock fragments scattered everywhere over the surface, embedded in the soil mass or occurring as knobs and points protruding through the soil from their undisturbed position in the underlying agglomerate (See Pl. I, fig. 1). The soil material is low in organic matter.

*Location.*—Several bodies of the soils of this group are encountered along the northeastern edge of the survey northwest of Oroville. The survey along this line would have been bounded by a continuous area of this group had the area been extended a few miles farther to the northeast, since the soils of the group are extensively developed in that direction. One area is mapped northeast of Lockeford at the edge of the area in the southeastern part of the survey.

*Topography and drainage.*—The general topography of this group would permit cultivation if other conditions were favorable. It is in places uneven, dissected or even precipitous along certain abrupt descents, such areas approaching the character of Rough stony land. In general, however, the surface consists of fairly uniform slopes, ridges, and plateaulike bodies varied here and there by the more pronounced topographic features. A large part of the area covered by this group in the northeastern part of the area forms the face of an escarpment leading from the flatter types of the valley floor up to the extensive, rather uniformly surfaced plains, the material continuing over wide areas to the eastward.

*Utilization.*—A part of these soils supports a growth of scrubby oaks and brush, but large areas are barren, except for grasses. The soils of the group are recognized as being nonagricultural, no cultivation being attempted. They afford rather scant pasture, which is

their only use. A few irregular patches occur, in which the soil is deep enough for tillage, but these constitute only 1 or 2 per cent of the total area of the group.

#### AIKEN LOAMS.

*Description.*—The Aiken loams as recognized in this survey include the undifferentiated loam and clay loam types of the Aiken series.

The Aiken loam consists of a rather sticky loam of average texture. There is considerable range in color, but shades of red predominate according to the variation of the parent rock, the extreme range being from pale to very deep red. The material in places has a silty texture, but sandy phases are rare. Small fragments of the parent rock are scattered throughout the soil mass, but these rarely influence tillage conditions. The transition from soil to rock material is usually more sharp than under similar conditions in the soils of the adjoining Sierra series. The type is variable in depth, but a heavier textured subsoil, usually a clay loam, generally occurs within a few inches of the surface. In rare instances the soil and subsoil have a total thickness of 72 inches, but as a rule bedrock is reached at depths of a few inches to 3 or 4 feet. The Aiken loam constitutes the greater part of the soils mapped under this group.

The Aiken clay loam closely resembles the loam in most of its features other than texture. It usually occupies the smoother areas of the group, or may accompany the weathering of rock masses of slightly different character than usual.

Mechanical analyses of samples of the soils and subsoils of the Aiken loams follow:

#### *Mechanical analyses of Aiken loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Aiken loam:								
20749, 20751.....	Soil.....	3.3	10.6	5.9	11.9	8.9	45.1	14.3
20750.....	Subsoil....	1.6	5.0	3.2	8.8	4.1	33.9	43.7
Aiken clay loam:								
12048, 12050.....	Soil.....	2.7	6.2	3.4	9.1	8.1	46.1	24.2
12049, 12051.....	Subsoil....	3.5	8.5	4.1	10.2	6.4	43.1	24.4

*Location.*—The Aiken loams occupy some rather extensive areas along the eastern edge of the survey from the vicinity of Oroville southward. The group usually occupies the highest general elevations in its locality. It occurs for the most part as the lower extensions or lower foothill areas, which occur much more extensively to the east. In one or two instances, such as near Palermo, the group occupies outlying hills surrounded by soils derived from old sedi-

mentary deposits, but in most cases the bodies included in this survey represent the beginning of the broad expanses of massive rocks bordering the valley proper.

*Topography and drainage.*—The Aiken loams have a widely diversified surface. The topography is hilly, in places uneven and broken, and drainage is excessive and erosion quite active. Many sloping or only moderately steep hillsides occur, and over large areas the general topography is favorable to tillage. Rock outcrop is so abundant in some areas as to make them suitable only for grazing.

*Utilization.*—A large part of the area covered by the soils of this group is treeless, but the higher areas support a scattered growth of oak with various conifers. In other places live oak and a growth of chaparral with a rather good grass growth is present.

With the exception of a few small orchards and some fields of grain, the soils of this group are utilized in this area only for grazing. They are usually above existing irrigation systems, and owing to this feature, together with their inability to grow a variety of crops under dry-farm methods, they have not been extensively developed. It is believed, however, that a wide range of crops is entirely possible upon all phases of these soils, of even moderate soil depth, wherever irrigation water can be supplied. Portions of the areas are probably well adapted to citrus fruit. Olives, English walnuts, and almonds, and plums, figs, cherries, peaches, pears, grapes, berries, and other fruits are being produced on this soil group in the region immediately east of this survey and the fruit is of high quality. Irrigation is the controlling factor and is now available for large areas. This group of soils is not popular for general farm crops because of the expense incident to its irrigation. Areas having the deepest soil covering are best suited to orcharding. A large part is unsuitable for any use other than for pasture, but there is much good soil throughout this now largely unused area. Blasting is of value in bringing those phases of the soil which are residual from rocks of schistose structure under cultivation.

#### ALTAMONT SERIES.

The soils of the Altamont series are brown to dark brown, becoming somewhat reddish brown when wet. The subsoils are light brown or yellowish brown, usually resting upon bedrock within 6 feet, although some areas are much more deeply weathered. Rock fragments frequently occur in the soil and subsoil. This series occupies rolling, hilly, or even mountainous country, and on the steeper slopes where erosion has occurred there is much rock outcrop. The soils are well drained, but retentive of moisture. They are residual in origin, being derived largely from Cretaceous and Tertiary interbedded sandstones and shales, with some conglomerate material in places.

In this survey the Altamont series includes several types which were previously mapped under the Sites series in the Sacramento and the Woodland areas, California.

ALTAMONT SOILS (UNDIFFERENTIATED).

*Description.*—The group of Altamont soils undifferentiated includes six types—fine sandy loam, sandy loam, loam, clay loam, clay loam adobe, and clay adobe. These soils vary somewhat in color and greatly in depth and texture within short distances. A brief description of each follows:

The Altamont fine sandy loam is one of the lightest colored members of the series. It consists of a light brown or yellowish brown, friable, fine sandy loam underlain by a lighter-colored and heavier textured subsoil. Bedrock is usually encountered at less than 6 feet. This type is of small extent.

The Altamont sandy loam is usually a light brown, or light reddish brown friable sandy loam, ranging in depth from a few inches to 3 feet or more, where the parent rock is encountered. The subsoil is often lighter colored. A slight variation occurs in which the soil is grayer than typical.

The Altamont loam consists of 12 to 48 inches of light-brown, brown or slightly reddish brown friable loam. The subsoil varies but it is generally lighter in color and heavier in texture, the parent rock being encountered at depths ranging from a few inches to 6 feet or more.

The Altamont clay loam consists of 12 to 48 inches of light-brown to dark-brown clay loam or silty clay loam, underlain by a light-brown or yellowish-brown subsoil of the same or heavier texture.

The Altamont clay loam adobe consists of a brown, dark-brown, or slightly reddish brown, sticky clay loam, which usually exhibits an adobe structure upon drying. Typically, the subsoil is lighter colored. It sometimes extends to a depth of 6 feet, but the parent rock is usually reached before this.

The Altamont clay adobe consists of a brown, dark-brown, or somewhat reddish brown clay having a well-developed adobe structure upon drying. The subsoil at from 2 to 4 feet is a yellowish-brown or light-brown clay loam or clay. Typically it is one of the darkest-colored types of the series.

A few dark-gray bodies of undifferentiated Diablo clay adobe were included with this group as were also some undifferentiated areas of the Sites series occurring along the west-central margin of the area.

Those areas of Altamont soils occurring in the southwestern part of the survey, such as on the Potrero Hills, on the isolated knolls and ridges within the Solano series, and in the low, hilly country north and south of Vacaville, consist for the most part of the sandy loams, loam, or clay loam members of the group and are of rather friable

structure. Much of this soil is shallow and poorly adapted to agriculture, but there is some good land included. Rock outcrop is frequent, but the entire surface of some of the lower hills and ridges is cultivated.

In one or two of the narrow areas in the vicinity of Cannon the soil has weathered very deeply and rock outcrop is not present. A great deal of the areas of this group west of Williams, Maxwell, and Willows, is much similar to the phases just described farther south, but the texture of the soil more nearly averages a clay loam or clay loam adobe. Farther north, opposite Williams and Germantown, the soil contains a few areas of Antioch and Montezuma material, and some angular or rounded gravel derived in some instances from material of the Corning series. A gravelly phase of this series, found in the Montezuma Hills, near Denverton, has a surface accumulation of waterworn gravel, which in some instances fills the soil and subsoil. A great deal of this phase is a gravelly loam or gravelly clay loam, the coarse materials being derived from the weathering of conglomerate beds associated with the other sedimentary rocks.

*Location.*—The soils of this series occupy scattered areas along the greater part of the western boundary of the area. One body is found in the extreme southwestern corner. Several detached areas, such as the Potrero Hills, Kirby Hill, and several others, occur well out in the valley slopes.

*Topography and drainage.*—The topography ranges from gently or sharply rolling to quite steep and hilly. There is great variation in the occurrence and amount of rock outcrop. The hills and slopes are usually free from it, but in the higher more eroded localities the material approaches Rough stony land. The rock exposed is mostly a rather durable sandstone, shales or impure limestones rarely appearing. Drainage is ample and even excessive on the shallower phases or lighter types of porous character.

*Utilization.*—Little forest or shrub growth is found upon these soils. More than half their area is used for pasturage. Considerable bodies, however, such as in the southwestern corner of the area and on many of the smoother ridges and rolling hills, give fair yields of grain during favorable seasons. A few orchards are maintained in a profitable condition without irrigation, but this is possible only for almonds, figs, olives, and crops requiring a minimum amount of water, and then only in the most favorable locations. A large lemon grove has been planted on the lower extension of this group west of Maxwell, water being supplied by pumping from gravity canals. The trees look thrifty and no doubt considerable areas of the better phases of this group could be successfully planted to citrus fruits, irrigation and local frost conditions being the controlling factors. As these soils generally lie above present irrigation systems they are little

utilized for intensive crops. On the lighter types some quickly maturing truck crops are grown before the supply of soil moisture is exhausted. When irrigated, the deeper areas are well adapted to the growing of cherries, apricots, plums, and peaches, but in planning commercial orcharding on this series frost conditions should be taken into consideration. The soils are usually not well suited to the general farm crops other than grain and grain hay.

#### MARIPOSA SERIES.

The soils of the Mariposa series are yellowish or light brownish yellow to grayish yellow in color and, so far as encountered in this survey, of shallow depth. There is little variation in the soil and subsoil and a bedrock substratum is usually found at much less than 6 feet. The surface is uneven or hilly, with numerous rock outcrops. These are residual soils, being derived from slates, previously referred to as the Mariposa slates. The series is not extensively developed in the Sacramento Valley area, but has been more extensively recognized along the Sierra foothills in the San Joaquin Valley.

#### MARIPOSA SILT LOAM.

*Description.*—The Mariposa silt loam consists of a yellow, grayish-yellow, or light brownish yellow silt loam with an average depth of about 3 feet. The soil is very smooth to the touch, having a feel resembling that of a highly micaceous soil, owing to the minute flattened slate particles which it contains. The texture is friable and no essential differences between soil and subsoil are noticeable, except that varying degrees of disintegration in the parent rock may be encountered within much less than 6 feet of the surface. Along hillsides or colluvial slopes and valleylike depressions a deeper soil covering may be accumulated, in places being 6 feet or more in depth.

*Location.*—Two or three small bodies of this type were encountered southeast of Sacramento along the eastern edge of the area. They occur in a region of practically no agricultural development, among soils of rather low value under present conditions, and were in the earlier detailed survey of the Sacramento area included within the nonagricultural material mapped as Rough stony land.

*Topography and drainage.*—The type covers hillside slopes of gentle to steep outline and is often much eroded. A rolling to hilly topography is the rule. Drainage is excessive. A very unusual appearance is given the surface by the frequent outcrops of long parallel lines of sharp points and upturned edges of the parent slate, which underlie the type in an almost vertical position.

*Utilization.*—The type is irregularly wooded with various trees and a brushy undergrowth characteristic of its locality. At present,

although the growth of grass is rather scanty and not very enduring, its sole utilization is as pasture land. It is as a whole poorly adapted to irrigation and of low agricultural value. There are small scattered areas having a deep soil and being free from rock which under irrigation would be suited to a wide range of crops, but their value is much decreased through their isolated location.

#### ARNOLD SERIES.

The Arnold series consists of gray, light-gray, or brownish-gray soils, occupying lower slopes and rolling margins of the east side valley plains. They are derived from the weathering of loosely consolidated sedimentary deposits of clay and sand. Small waterworn gravel sometimes occur, usually as an uneroded remnant of the associated Redding series. The subsoils are usually heavier textured than the surface soils and often rest upon the original soil-forming materials within 6 feet of the surface. These soils are typically developed in areas of limited extent along the lower foothills of the Sierra Nevada Mountains, bordering the San Joaquin and Sacramento Valleys, merging into the lower-lying red soils of the San Joaquin series upon the one hand and into the residual soils of the Sierra and Aiken series upon the other. Some areas of the series are overlain by the Redding soils. Drainage is well developed and in places excessive.

#### ARNOLD SANDY LOAM.

*Description.*—The soil of the Arnold sandy loam consists of a gray, light-gray, or brownish-gray sandy loam of a rather loose, friable structure. This material often attains a depth of 6 feet or more, but may grade at any depth below 2 or 3 feet into a grayish-brown or reddish-brown loam or clay loam. The latter colored subsoil is usually found on hilltops. The heavier textured subsoils are sometimes supplanted by the soft gray or brownish parent material. Both soil and subsoil absorb rainfall readily and retain it remarkably well considering the surface slope and the texture of the soil. A small amount of waterworn gravel is scattered over the surface in places, being largely derived from remnants of the Redding gravelly loams which occasionally remain as disappearing patches capping hilltops or ridges. The surface soil is often quite gritty with a correspondingly greater clay content in the subsoil, indicating the filtering of fine material downward. Minor included bodies of fine sandy loam and loam occur, but are poorly developed and too small to indicate upon the map in this survey.

*Location.*—This type was encountered in several bodies along the eastern edge of the area from the vicinity of Roseville southward. It occurs in association with the soils of the San Joaquin series, the Arnold loams, and the various other soils occupying the margin of



complex rock and soil conditions lying between the main valley trough and the massive rocks of the lower foothills.

*Topography and drainage.*—The topography of the Arnold sandy loam is prevailingly gently rolling, very steep or broken slopes incapable of cultivation being rare (See Pl. I, fig. 2). Erosion is active but proceeds quite uniformly, so that even though surface drainage is in places excessive, little damage results from washing or gullyng. Rock outcrop is rare.

*Utilization.*—This type originally supported a scattered growth of oaks, but most of these have been removed as the cultivated areas have been extended. Nearly all of the type is capable of cultivation. It has been used many years for grain farming, producing good yields. Portions of it around Fair Oaks are highly developed, producing oranges, olives, almonds, figs, and other intensive crops. Irrigation is generally necessary for the production of all crops except grain. The surface features and the elevated, outlying position of the type make irrigation quite difficult and expensive, but wherever it has been supplied the soil has shown its adaptation to a wide range of intensive, highly specialized crops.

#### ARNOLD LOAMS, SHALLOW PHASE.

*Description.*—The Arnold loams, shallow phase, as mapped in this area consist for the most part of gray, ashen-gray, or slightly brownish soils. They are of a prevailingly shallow and barren character, and are recognized as a shallow phase of the material as typically developed. A rather sticky loam usually occurs, but inclosed bodies of both lighter and heavier textures are also found. The surface soil gives way at a depth of 4 to 20 inches to comparatively hard, dense, fine-grained sandstones or indurated, silty beds, extending to great depths. The soil is normally rather compact, low in organic matter, and apparently a poor farming soil. It has a very low water-holding capacity.

*Location.*—The Arnold loams, shallow phase, occupy several extensive bodies in the southeastern part of the area. The Redding gravelly loams in this locality once covered the material of this group as an unbroken plain, but this has now been reduced by erosion to its present condition of isolated upland remnants disconnected from the lower foothills. In the basinlike areas between these remnants the Arnold loams occur.

*Topography and drainage.*—The soil group occupies two distinctly different topographic situations. The greater part of it consists of small hills or steep, closely set, miniature buttes separated by narrow strips of smoother contour. In these rougher portions exposures of the edges of harder horizontal layers of parent material left by the destructive erosion of the massive beds is frequent. Loose rock

fragments are rare, but well-rounded cobbles of quartzite are plentifully scattered over the surface in places, being the last vestiges of the disappearing Redding gravelly loams which formerly overlay the material of this group and even yet remain as a covering over small areas. This steep and most severely eroded portion of this group constitutes its most shallow phase, being practically nonagricultural and in some instances even resembling Rough stony land. A smoother phase is also included which lacks the numerous rock outcrops and broken topography just described, and in addition has a slightly deeper soil covering and a higher possibility for development. A "hog-wallow" surface often characterizes the flatter phase, and drainage is not so excessive as elsewhere.

The soil body lying southeast of Michigan Bar consists of steep sloped hills capped with brown sandstone, with intervening rolling valleys, and is recognized as being unlike the typical group. The soil is here gray, but carries considerable percentages of quartz gravel in places. It is also modified to an uncertain extent by the complexity of the rocks of the locality.

*Utilization.*—The soils of this group are usually very barren of tree growth and afford even scant pasture. Southeast of Michigan Bar a thick growth of manzanita and such brushy covering is found, with an occasional oak or pine along the drainage courses. Practically none of the area covered is tilled, being held in very low esteem for agriculture. It is used only for pasture. Without irrigation fruit growing is impracticable, and even on the best portions of the soil it can be made only fairly profitable by irrigation.

#### BUTTE SERIES.

The soils of the Butte series are gray and in this area without distinct subsoils, the parent rock being usually encountered at a depth of a few inches. The gray color is derived from the partially disintegrated gray andesitic rock weathered in place. This series is confined to the Marysville Buttes near the central part of the area. The soil material is frequently broken by rock outcrop, and the series is in this survey of minor importance and of inextensive occurrence.

#### BUTTE STONY SOILS (UNDIFFERENTIATED).

These soils are gray in color, but aside from this feature resemble the Aiken stony soils (undifferentiated), being practically identical with them in texture, depth, general surface features, and nonagricultural character. The soil material is very shallow, rarely exceeding 6 inches, and rests upon gray andesitic rock. The group occupies the lower slopes of the Marysville Buttes, being the less rugged yet rocky areas reaching from their rough central region to the recent alluvial fans about their border.

## DIABLO SERIES.

The Diablo series was not extensively mapped in this area. The soils are typically dark gray or black in color, becoming darker when wet. The subsoils are calcareous, resting upon the underlying rock within an average depth of less than 6 feet and are often lighter in color than the surface soils, being various shades of gray or brown. At times the black soil rests directly upon the parent rock. They are usually identified with the most calcareous rocks. The soils are well drained, but retentive of moisture. The series occupies a rolling to hilly country in the southwestern part of the survey. These soils are practically treeless and are dry-farmed to hay and grain. One type, the clay adobe, was recognized.

These soils are residual from the calcareous shales or impure limestones of the Coast Range of mountains, the rocks being largely of Cretaceous and Tertiary age.

## DIABLO CLAY ADOBE.

*Description.*—The Diablo clay adobe typically consists of a very dark gray, slate-colored, drab, to black sticky clay of pronounced adobe structure. This material may extend to a depth of 6 feet or the subsoil may occur from 24 inches downward as lighter colored clay. Frequently the parent rock is encountered within 2 or 3 feet, but usually at greater depths. Rock outcrop, as points or ledges, is rather infrequent, but, when occurring, appears more often as entire rocky slopes or entire hills than as jutting points marring the continuity of the typical soil. The type is easy to cultivate, granulation no doubt being greatly aided by a high content of lime from the parent rock. It is very sticky when wet, but dries rapidly, checking and cracking to such an extent that it leaves a very mellow surface.

*Location.*—One single area of the Diablo clay adobe as a differentiated type occurs in the extreme southwestern corner of the survey. It is there quite typically developed over a considerable area, but is defined by a somewhat arbitrary boundary from the Altamont soils bordering it on the south.

*Topography and drainage.*—The type occupies steeply rolling country. It is dissected by intermittent stream channels and deep ravines. Small land slides occasionally occur during seasons of unusual rainfall. The drainage is ample but not excessive, the soil having a remarkable power to absorb and retain water.

*Utilization.*—The type is treeless, and almost all of it is under cultivation. Wheat hay is practically the only crop grown, alternate summer fallowing and cropping being the rule. Much of the crop is hauled down the hills on sleds to points where it can be loaded on wagons. An average yield of about 2 tons of hay per acre is obtained.

## SOILS FROM OLD VALLEY FILLING MATERIAL.

## REDDING SERIES.

The Redding series of soils range in color from red to deep red, with small areas of yellowish red. The color in some areas is influenced by the gray sedimentary rocks giving rise to the Arnold series where these underlie the Redding material, occasionally at shallow depth. Typically the color is a more pronounced red than in the San Joaquin series. Nearly all the soils carry large quantities of quartzose gravel, which is mainly well rounded to subangular, and ranges in size from small gravel to fragments 3 or 4 inches in diameter. The gravelly loams and sandy loams prevail. The soil profile is variable, but most often the material is a gravelly loam to about 16 inches, where a deep-red compact clay loam or clay is encountered. This is relatively free from gravel and only a few inches in thickness. It rests upon a distinctly red, iron-clay hardpan, from an inch to several inches thick, and relatively impervious to both roots and water. It grades downward through lessening degrees of cementation into substrata of gravel or very gravelly beds with interstitial fine soil material. In some places this gravelly substratum is partly cemented. Those areas in which the subsoil grades into gravelly beds without an intervening distinct hardpan are recognized as more like the Corning series. In some instances a thin veneer of Redding soil material remains upon consolidated material, giving rise to the Arnold series. The Redding series occupies level or gently sloping, to undulating or rolling areas with surfaces elevated above the present stream valleys. The general drainage is excessive, but the soils are periodically boggy through lack of underdrainage. A general tendency toward a "hog-wallow" surface accentuates this condition by arresting the run-off from inclosed minor depressions. The series is usually treeless except on more elevated areas where a rather scrubby growth of oak and pine with manzanita and other shrubs and bushes occurs. This series occupies remnants of an old extensive plain of Pleistocene deposition which have been modified by weathering, erosion, and the formation of the hardpans. The soils are not well adapted to fruit culture without irrigation. A large part of the series is devoted to pasturage, and nearly all the remainder to grain production. The shallower areas are not adapted to deep-rooted fruits, but with irrigation these soils produce a wide range of shallow-rooted fruits, berries, and olives, while the deeper-rooted fruits are profitably grown upon the areas of deeper soil.

## REDDING GRAVELLY LOAMS.

*Description.*—The Redding gravelly loams comprise the gravelly loam and the gravelly sandy loam of the Redding series.

The Redding gravelly loam consists of a red to deep red loam, the color being a shade more pronounced than in the San Joaquin series.

It contains large quantities of gravel, mainly well rounded to sub-angular, and ranging in size from small gravel to fragments 3 or 4 inches in diameter. Practically all this gravel is quartzose rock.

The soil profile is extremely variable, but most often this gravelly loam extends to a depth of about 16 inches, where a deep red compact, clay loam or clay, which is relatively free from gravel, is encountered. These heavy subsoils are only a few inches in thickness and rest upon a distinctly red iron-clay hardpan, relatively impervious to both roots and water, and from 1 to several inches thick. The hardpan grades through lessening degrees of cementation into substrata of gravel, or very gravelly beds with interstitial fine soil material, which extend to depths of several feet.

The Redding gravelly sandy loam consists of a sticky sandy loam resembling the gravelly loam in gravel content, depth, and other features. In the northern part of the area it averages slightly deeper than the gravelly loam of the same region. It is not extensively developed.

The Redding gravelly loams are subject to considerable variation in color, texture, and arrangement in the soil profile. Some of the phases on the west side of the valley in its northern extension are shallower and of relatively low agricultural value. In these places the gravelly substrata below the hardpan are sometimes cemented and are often nearly free from interstitial material. In these localities the total depth available to plant roots and for the storing of moisture seldom exceeds 24 inches. Throughout large areas the cemented gravel interferes with root development, even where the overlying hardpan is shattered by blasting. Some of the more elevated forested areas around the head of the valley have a yellowish-red color and a deeper soil covering than is typical. The hardpan under some of this phase is absent and the heavy subsoils rest directly upon the partly cemented sand and gravel beds. The disintegration of the underlying material adds somewhat to the agricultural value of this soil.

In the more nearly level, extensive bodies of this type, there are local phases approaching a clay loam. These are often associated with small, poorly drained flats.

The large body in the vicinity of Oroville is subject to wide variation, and has a wide range in agricultural value. The soil is several feet deep over considerable areas and grades into gravelly beds without an intervening hardpan. In other phases it consists of gravelly loams from the surface downward. Those areas grading into gravelly substrata without hardpan are more like the Corning series. In some instances a thin veneer of Redding soil material remains upon the gray substratum, giving rise to the Arnold series, and in such localities the color is sometimes a grayish red. The entire type is moderately easy to till under proper moisture conditions.

The following table gives the results of mechanical analyses of samples of the soils and subsoils of the Redding gravelly loams:

*Mechanical analyses of Redding gravelly loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Redding gravelly loam:		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24152.....	Soil.....	3.5	7.3	5.1	12.4	20.2	42.1	9.2
24153.....	Subsoil....	4.2	4.2	2.9	6.6	17.8	22.5	42.1
Redding gravelly sandy loam:								
24157.....	Soil.....	4.1	11.2	8.0	14.4	17.7	30.1	13.8
24158.....	Subsoil....	5.3	8.0	5.1	9.2	24.1	18.9	29.2

*Location.*—The Redding gravelly loams are extensively developed in this area. They occupy broad areas on the west side of the valley from near Corning northward. On the east side of the valley they are important soils from the vicinity of Oroville southward to the boundary of the area.

*Topography and drainage.*—The Redding gravelly loams occupy level or gently sloping to undulating or rolling areas. Although the surface is modified by streams, only the more northerly areas can be called dissected. In general, these soils occupy a broad, rolling, elevated plain with general surfaces elevated above the present stream valleys and a general slope toward the valley trough. Some of the areas occur as isolated hills or ridges within the San Joaquin series. The soils of this group usually rise in elevation above the surrounding soils, except where they border the more elevated residual soils of the lower foothill regions. They consist largely of ridges or elevated areas jutting into this survey from more extensive bodies without the area. In general surface conditions favor drainage, but the soils are periodically boggy through lack of underdrainage. A general tendency toward a "hog wallow" surface aids in producing this condition by arresting the run-off from inclosed minor depressions. No alkali occurs.

*Native vegetation.*—Nearly all the Redding gravelly loams in this area are treeless and barren, but notable exceptions occur in the more elevated areas about the head of the valley and in other smaller areas along the eastern margin, where the soils are covered with a natural growth of upland oak, ceanothus, manzanita, and considerable brush.

*Utilization.*—It is recognized that these soils are poorly adapted to the growing of fruits without irrigation and that they are only moderately productive when dry-farmed to grain. Nearly all of their present cultivated area is used for grain, although large areas are devoted to pasturage. In a very few inextensive areas the group has been intensively irrigated and has proven well adapted to a number of fruit crops. The larger bodies of the group are elevated above existing

irrigation systems. A large part of the soil is capable of eventually being watered by pumping from gravity canals or subsurface waters.

The shallowest areas are not adapted to deep-rooted crops, but the average soils are capable of producing olives, figs, grapes, peaches, and a variety of berries. Citrus fruits can be grown in a few places where frost conditions are favorable. These crops do best on these soils, but many others are possible. Blasting is generally necessary in order to shatter the hardpan to enlarge the root zone and promote subsurface drainage.

The elevated position, unusually good air and soil drainage, and freedom from alkali make these soils especially well suited to the crops mentioned.

#### SAN JOAQUIN SERIES.

The San Joaquin soils, often locally known as "red hardpan lands," are prevailingly red or pale red in color, and range in texture from a sandy loam to a clay loam or heavier material, usually free from gravel, but often gritty. At less than 6 feet a red or mottled, relatively impervious hardpan, in which iron compounds are the principal cementing material, is encountered. A layer of heavier textured subsoil generally of deeper red color usually intervenes between the soil and the hardpan. Sand, clay, and even gravel are included in varying proportions in these indurated layers. The combined depth of soil and subsoil varies widely, but averages between 2 and 3 feet, although the position of the hardpan ranges from surface exposures to depths of several feet. The soils of this series occupy sloping to undulating or rolling valley plains, usually extending from the lower rolling foothills down to the more nearly level floors of present stream bottoms. Their average elevation is greater than any of the recent alluvial or basin soils, yet lower than the Redding series and the residual soils derived from higher marginal valley deposits or lower foothill rocks. The general topography favors good drainage but the hardpan and the usual development of "hog-wallow" mounds with inclosed depressions retard subsurface drainage and run-off, and boggy conditions during the rainy season are the rule. On the other hand, during the dry season the soils are dry and hard, flinty, compact, and baked when not cultivated. Practically no tendency toward alkali is found. The series is derived from extensive remnants of Pleistocene sediments now occurring as treeless plains. These soils are largely devoted to dry-farmed grains, but under irrigation have proved well adapted to a wide range of fruit crops.

#### SAN JOAQUIN LOAMS.

*Description.*—The San Joaquin loams include the loam, fine sandy loam, and sandy loam of the San Joaquin series.

The San Joaquin loam comprises perhaps 80 per cent of the area occupied by the group as mapped and consists of a red, light-red, or

dull-red loam. The soil is usually rather smooth, silty or sticky, but often carries a large percentage of coarse or gritty material which affects cultivation, and is plainly evident to the feel or even accumulates on the surface as a light sandy layer. The soil is usually heavier, sometimes with adobe tendencies, in the many low, undrained depressions which characterize the surface. Widely different features of structure and tilth occur within short distances under different conditions of moisture. The best drained areas are rather friable at all times, but the general tendency of this type to become water-logged during the wet season makes it difficult to handle. This surface soil is underlain by a heavy, compact, red-clay loam or clay at depths varying from 12 to 36 inches and averaging about 2 feet. These denser subsoils nearly always give way within a few inches to a red rather dense hardpan that is impervious to both roots and water. This hardpan layer is recognized as characteristic of the type and, while it is subject to wide variation in character and depth, it can be said to occur in 90 per cent of the loam group within 4 feet of the surface. Over a large part of the type, this impervious hardpan layer occurs at depths of 12 to 24 inches. The character of these indurated layers varies widely, and they have an important and varying influence upon the agricultural value of the land. In the better areas the hardpan layer is encountered at depths of 4 to 6 feet, and consists simply of a thin plate of iron-cemented clay, passing downward into good soil material. Under such conditions blasting gives beneficial results for all deep-rooted crops, and is not necessary for the shallower rooted crops. In the most unfavorable areas, these cemented beds lie only a few inches below the surface, or may be exposed and continue as reddish or mottled, rather firmly indurated beds, to a depth of 6 feet or more. Blasting in this instance is not generally helpful, and may, on the other hand, prove injurious. Between these two extremes there are all manner of gradations. The true hardpan of wholly impenetrable nature is sometimes supplanted by incipient hardpans of only partially cemented character, or the hardpan may consist of a thin layer of hard material in conjunction with other layers partially cemented. It is believed that the cementing material in nearly all instances consists of iron compounds, but in many cases the hardpan is mottled and streaked with gray material. In areas northeast and also southeast of Sacramento the soil grades within a few inches of the surface into a rather well-defined red hardpan, which in turn passes into grayish cemented beds extending to 6 feet or more.

The San Joaquin fine sandy loam member of the group consists of 18 to 36 inches of red or reddish-brown fine sandy loam, sometimes underlain by a darker red fine sandy loam, or by red loam or clay loam. A red or mottled hardpan, typical of the series, is usually



encountered within a depth of 36 inches. The profile varies considerably, as in the American Basin, where the hardpan usually lies within 2 feet of, and often outcrops at, the surface. Like the other members of the series, the soil is sticky when wet, and where not cultivated becomes hard and compact upon drying.

The San Joaquin sandy loam is subject to wide variations in the soil profile. The surface soil consists of from 18 to 72 inches of red, sticky, sandy loam, carrying small, angular rock fragments. In some places it continues throughout the 6 foot soil section, and in others has a depth of only about 18 inches. Where other material is encountered in the soil section it consists of a red, sticky clay loam or loam, which in turn is underlain within a few inches by the typical hardpan of the series. This type does not have any uniform features other than texture to distinguish it from the loam member.

Throughout the extent of the San Joaquin loams there occur small bodies of soil where the true ferruginous hardpan is entirely absent and only highly compact red subsoils are found. These subsoils when exposed to the air become cracked and hard, and in their natural covered positions are no doubt rather impervious to roots, but this hardpan-free phase is distinctly superior to the remainder of the group, and in many instances constitutes a good agricultural soil. Such areas are scattered throughout the San Joaquin area and contrast strongly in agricultural possibilities with the shallowest phases.

In addition to the types described, this group includes certain variations tending toward a clay loam. These are of small extent and are usually associated with the more puddled and flatter areas.

The San Joaquin loams group throughout its extent is marked by small local depressions in which the soil is dark gray or black and belongs properly to the Alamo series.

The following table gives the results of mechanical analyses of samples of the soils and subsoils of the San Joaquin loams:

*Mechanical analyses of San Joaquin loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
San Joaquin loam:								
20740, 20742....	Soil.....	1.3	8.1	4.5	9.6	14.2	41.9	20.2
20741, 20743....	Subsoil....	.9	5.6	3.3	9.9	9.8	32.9	37.7
San Joaquin fine sandy loam:								
20736.....	Soil.....	.7	10.2	9.7	14.5	14.9	28.3	21.6
20737.....	Subsoil....	.7	10.7	9.5	15.3	9.3	27.6	27.1
San Joaquin sandy loam:								
20735.....	Soil.....	1.9	14.6	10.3	19.5	19.0	17.8	16.5

*Location.*—The San Joaquin loams comprise one of the most extensive and important bodies of soils in the area. The group is confined to the east side of the valley and occupies broad valley plains as the predominant soil for great distances. Commencing with a large body a short distance south of Palermo, the San Joaquin loams continue in interrupted areas to the southern edge of the survey. Aside from the valleys of river courses with their alluvial bottoms crossing this plain from the eastward, the group occupies an unbroken plain.

*Topography and drainage.*—Broadly viewed, the San Joaquin loams occupy the remnants of a former extensive plain, reaching from the lower foothills of the Sierra to the valley trough. This has been reduced by erosion until at present there remain only segments, isolated between the numerous streams flowing from the east. Erosion by waters along the main trough of the valley has likewise tended to decrease the extent of these old plains, as is indicated by some of the outlying fragments in American Basin and elsewhere. The general surface of the San Joaquin loams is rolling and dissected by numerous small drainage ways. These numerous swales and the rather good average slope of the region would ordinarily give excellent drainage, but peculiar minor topographic features and the general hardpan condition prevent. Nearly all the surface of the types is marked by what are locally called "hog wallows," which are rather striking small mounds a few inches to 2 or 3 feet or more in height with intervening depressions. These are rather uniformly distributed over both flats and slopes. They are usually from 10 to 50 feet in diameter, closely set, and include numerous inclosed depressions. During the rainy season both soil and subsoil become saturated and water fills these minor depressions, only the excess water draining away over the surface. Much water is thus retained in the small depressions and subsoil, since subsurface drainage is arrested by the hardpan layers. In this manner the greater part of the soils of this group is waterlogged and boggy throughout the rainy season, though the soil soon dries through evaporation and the moving of water laterally along the surface of the hardpan when precipitation ceases. This boggy condition is then succeeded during the dry season by a very dry condition, the surface, when uncultivated, becoming flinty and baked. The long rainless period permits the soil to become almost air dry to the depth of the hardpan. Owing to their elevated position these soils are not subject to overflow except in small strips along interior drainage ways or across its lowest extensions along the flood plains of the larger streams. It is thus apparent that through the physical peculiarities of these soils and the detailed surface features the group is annually subjected to extreme moisture.

*Utilization.*—Nearly all this group is devoted to the production of dry-farmed grain or grain hay under summer-fallowing methods. Some areas are pastured. Typically the soils are not well adapted to intensive crops without irrigation, and the fact that these soils are somewhat elevated, low in organic matter, often shallow in character, and irregular in surface features, tends to check their agricultural development as compared with some other adjoining soils. The soils of this group usually lie above existing irrigation systems, and are often held in large tracts. The deep phases are utilized in a small way for the production of grapes, olives, figs, and a few other crops without irrigation, but the yields are low and uncertain. Experience has shown that irrigation is the controlling factor upon these soils in the production of intensive crops. The soils have been developed in various localities by irrigation from gravity systems and pumping, and are now profitable producers of many crops. Chief among these are olives, grapes, figs, peaches, berries, plums, and other fruits. Some fields of alfalfa upon the deeper phases produce good yields, but this crop in the shallower areas is short lived. Its water requirements are high. Citrus fruits are grown on a commercial scale on this series in the San Joaquin Valley where frost conditions are favorable, but the success of these fruits on this group in the Sacramento Valley has not yet been fully demonstrated. Many of the truck crops are grown for home use about ranch houses, and commercially in a small way. The yields indicate that these soils are suited to a wide variety of such crops. Although the soils of this group are adapted to a wide range of crops, they have been neglected for the development of other soils which are better suited to intensive cultivation. The shallow phases of the group may be utilized for deep-rooted crops where the hardpan is not too thick for successful blasting and is underlain by material permeable to roots. The deepest phases are good soils, but constitute only a small percentage of the group.

SAN JOAQUIN AND ARNOLD<sup>1</sup> LOAMS (UNDIFFERENTIATED).

*Description.*—The San Joaquin and Arnold loams (undifferentiated) comprise areas of soil of these series, the material grading from the typical soil of one series into that of the other within short distances. These soils are so intricately arranged that their separation on this soil map is not practicable. It would be difficult properly to separate them on a detailed map where they are most intimately mixed. The soils of this group range in texture from a loam to sandy loam, the soils of the former texture belonging mainly to the San Joaquin series, and those of the latter to the Arnold series. Wherever possible, distinct areas of soil of these series are separated on the map and classed

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<sup>1</sup> Though mapped with the San Joaquin loams, the Arnold differs in origin, being residual.

with the proper series. The topography of this group is rolling to rather hilly.

Soils of this group belonging to the San Joaquin series consist of red or light-red material. They occupy the higher crests, ridge areas, and upper slopes. These soils are usually a little better drained and have a less pronounced hog-wallow topography and a slightly deeper soil covering than is typically found in the broad areas of San Joaquin loams, which are described elsewhere in this report. The hardpan of the San Joaquin series is present in places, and where absent there is in places a substratum of the gray indurated beds common to the Arnold series (see Pl. II, fig. 1). There are patches of typical San Joaquin loam, but much of the material is too brownish in color for that series. On the other hand, those areas of these undifferentiated soils most nearly approaching the typical Arnold sandy loam are rather too brown for that type. Some grayish bodies, however, are identified as Arnold sandy loam, and the description of that type fits about 50 per cent of this group. Much of the region about Roseville has been considerably modified by the transportation of angular gritty material derived from the extensive areas of granodiorite occurring to the east.

*Location.*—The largest area of this group occurs about Roseville, extending southward to Fair Oaks. Many other smaller bodies occupying about the same relative position along the valley slopes occur south of this region, extending to the boundary of the survey.

*Topography and drainage.*—The surface is gently undulating or steeply rolling, yet there are very few slopes which can not be tilled (see Pl. I, fig. 2). Erosion is rather uniform over the surface, and the land is dissected in only a few places. General surface drainage is good and there is no tendency toward the accumulation of alkali. Some of the smoother areas of the San Joaquin soils in this group become waterlogged during the rainy season, as a result of poor drainage.

*Utilization.*—The soils are often timbered, but much of the original forest has been removed. The greater part of the land is utilized for grain farming or pasture. Good results have been secured in the production of fruits wherever irrigation water has been available. Around Fair Oaks these soils are highly developed to citrus fruits, olives, almonds, and figs, and in the vicinity of Roseville to vineyards and deciduous fruits. A large part of their area is well adapted to intensive agriculture. The good air drainage and other features make the larger part of it very well adapted to fruits. Good yields of grain are secured. Some profitable orchards are maintained under dry-farming methods, but in general irrigation is necessary for commercial fruit growing.

## CORNING SERIES.

The soils of the Corning series are red in color, with phases of yellowish red or light red. They are easily puddled, boggy when wet, and difficult to handle except under proper moisture conditions. The subsoils are red to deep red, of heavy, compact structure, slightly impervious to moisture, and usually pass into gravelly substrata, within the 6-foot depth. These soils are derived from Pleistocene or early Quaternary sedimentary deposits now constituting elevated terraces or remnants of an older valley filling, which have been somewhat altered or reworked. They occupy sloping to undulating or hilly uplands and valley plains. The surface is frequently marked by "hog-wallow" mounds and depressions, and there are local poorly drained areas. The members of this series are usually treeless. These soils are much like the Redding in topography, color, and origin, and both series have gravelly substrata, but the hardpan of the Redding series is not typically developed in the Corning series. The soils of this series are poorly adapted to general farming and fruit production under dry-farming methods.

## CORNING GRAVELLY LOAM.

*Description.*—The Corning gravelly loam prevailing consists of a red loam containing coarse sand and other gritty material, together with varying quantities of small, angular, or waterworn gravel. Very rarely the coarser gravel attains a diameter of 3 or 4 inches, but it usually averages much smaller and does not seriously interfere with cultivation. As in the Redding series, quartz greatly predominates in this coarse material. The humus content is low, but is easily increased under irrigation by the growth of green-manuring crops. The color is often light red or yellowish red in small areas, generally where this type grades into associated soils. The type is boggy when wet and quite compact in structure when dry, closely approaching the Redding gravelly loam in these features. The wide distribution of this type, variation in the character of the original material, the variable effects of erosion, and in certain instances the shallowness of the material result in uncertain subsoil conditions. In its average occurrence, however, the surface gravelly loam grades at 12 to 20 inches into a deep-red, compact, heavy clay or clay loam, which is practically free from gravel and becomes very hard and cracked when exposed. This is in turn underlain at depths of 24 to 48 inches by layers of fine, waterworn gravel, clay, or beds of yellow, smooth-textured silt.

There is considerable variation from this typical Corning gravelly loam in various parts of the area. In the locality north of Corning where the red, gravelly deposits are classed with the Corning rather

than the Redding series, several gradations occur between these two series. Here the heavy subsoil underlying the gravelly loam occasionally rests upon a well-defined hardpan layer, making the type quite similar to the Redding gravelly loam. The clay subsoil itself occurs in a partially cemented state, and is only slowly penetrated by water. Even in these northern areas, where this type merges with the Redding gravelly loams, it does not have a distinct hardpan layer, but subsoil conditions are unfavorable. The gravel, silt, or clay usually encountered 2 to 4 feet below the surface is partially cemented and rather impenetrable to plant roots. In these localities an average depth of perhaps 30 inches is available for root development, except on slopes or in small areas where a slight wash has resulted in the accumulation of a deeper covering. Proceeding down the west side of the valley the various areas of this type exhibit an increasing tendency toward subsoils of loose, friable character, only slightly compact or partially cemented. In almost any locality considerable areas are found in which the gravelly loam extends to a depth of 6 feet or more, but the general rule is for the gravel content to increase with depth, and until the greater part of the type may be said to have a gravelly substratum within 6 feet.

The areas west of Oroville are not typical in their subsoil features. Beds of grayish compact or even partially cemented material underlie some parts but on the whole they are more like the Corning than the Redding series.

Some sandy loam is included in this type as mapped, but this is of small extent, and does not seem to vary from the loam in any particular except texture.

The rather large body of this type mapped east of Sacramento is not typical. This is an old terrace or reworked area, but the soil profile generally shows a marked similarity to much of the Corning gravelly loam as mapped on the western side of the valley.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil:

*Mechanical analyses of Corning gravelly loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24107, 24110.....	Soil.....	6.8	13.0	7.9	10.1	8.8	41.4	11.9
24108, 24111.....	Subsoil.....	5.6	7.4	4.4	6.4	5.4	33.3	37.2

*Location.*—This type is of most widespread occurrence on the west side of the valley, and occurs as scattered remnants of a once much more extensive plain. Some rather extensive areas are encountered in the lower foothill region westward from Orland and northward

from that locality to the Corning section. Some of the largest of these occur as the points of ridges extending into this area from the west. Several large bodies east of Corning and Kirkwood rise in elevation above all the surrounding soils. The type for a considerable distance along the foothills southward from Willows is practically absent, but it is well developed from a point southwest of Williams southward for many miles.

It includes the greater part of the type mapped in the previously surveyed Colusa area as the San Joaquin gravelly loam, which is now recognized as Corning material.

*Topography and drainage.*—The surface is usually sharply rolling, eroded by small streams, and quite often has a pronounced hog-wallow configuration. The broader areas of the type are sometimes rather even-surfaced fragments of the old plain. Because of its elevated position, it often presents a marked contrast to the flatter types of the surrounding series. It is practically always the highest lying type of its locality, occurring as a veneer capping certain older sedimentary material, such as that giving rise to the Antioch and Montezuma soils, undifferentiated. This is especially apparent north and south of Winters, where the latter group contains many remnants of this type which can not be shown on the soil map. The region between Davisville and Esparto is characterized by occasional low knobs which represent the last stages in that locality of the disappearing Corning material. Many of these are too small to indicate on the map and others are recognized as phases of the Corning gravelly loam, with which they are shown wherever feasible.

The Corning gravelly loam, because of its elevation and general surface features, has good drainage as a rule, but many small depressions collect water which at times does not readily escape through subsurface layers. A little smoothing of the surface, however, makes the soil fairly well drained except during periods of greatest rainfall. The areas are practically devoid of trees and brush, a notable exception to this condition being found in the wooded, brushy ridges and slopes southwest of Arbuckle.

*Utilization.* Only a small part of this type is tilled. In times past nearly all of it was utilized for grain production, and this use continues in areas which give good yields. Much of it has been used as pasture land for many years, but patches which have been irrigated indicate that the type is capable of producing good yields of a variety of crops. In general, the main bodies can not be extensively developed for agriculture without irrigation, except in the better phases. Fruit production is impracticable without irrigation. Efforts in the past to colonize this type upon a dry-farm basis failed. Some irrigation by pumping from underground sources is practiced near Corning and gives good results. (See Pl. II, fig. 2.) It is doubtful whether the

type can be sufficiently developed in most cases by the use of water derived from underground sources in its locality, because of its relatively high position and because the water is usually scarce and pumping expensive. Some areas, because of their hilly isolated position, can not be irrigated by any gravity canal.

Some success is had with the citrus fruit industry near Corning, the fruit being of good quality. Peaches, almonds, grapes, olives, and figs yield well with irrigation, and are profitable where the cost of supplying water is not excessive. Irrigation is the controlling factor in the agricultural use of this soil. Much of it is barren and unproductive at this time and its future development will depend largely on extensive high-lying gravity systems of irrigation.

#### KIMBALL SERIES.

The Kimball soils are light-red or red to yellowish-red in color. The subsoils are red and usually heavier than the soils. They are either gravel free or the gravel is embedded in clay in such a way and in such quantity that it does not affect the drainage or water-holding capacity of the subsoil. The soil is usually sticky when wet, subdrainage is somewhat restricted, and the subsoil is compact, though not true hardpan, and rests upon a yellowish or yellowish red or yellowish gray very compact and sometimes slightly cemented substratum of fine gravel, sand, silt, and clay. This series is closely associated with the Corning and with the Redding and Tehama soils, differing from the former in the nature of the subsoil and from the latter in color. It is derived from old valley-filling material, consisting mainly of quartzitic and igneous rocks. The topography is undulating to rolling.

#### KIMBALL LOAM.

*Description.*—The Kimball loam, as typically developed, consists of a light-red to red, slightly sticky loam extending to depths varying from 16 to 30 inches. In places the soil is yellowish red. The type is sometimes slightly gravelly, the coarse sand and gravelly material corresponding to that found in the Corning gravelly loam. The material is slightly compact, and has a slight tendency to clod and puddle. A good tilth is easily secured, with careful handling, under proper moisture conditions. At an average depth of 24 inches the soil is underlain by a heavy clay loam or clay, which is very compact and shows adobe tendencies on exposure. Its dense structure is modified at times by the presence of small quantities of sand. The sand is rarely present in sufficient quantities to render the subsoil friable. This refractory subsoil may extend to a depth of 6 feet. Over the greater part of the type, however, it grades sharply at varying depths into a rather compact or even slightly cemented mass of



clay, sand, and fine gravel. This material corresponds quite closely with some of those masses encountered in the Redding series below the hardpan, or with the subsoil conditions typical of the Corning gravelly loam. The Kimball loam does not have a true hardpan, but plant roots are often practically limited to the surface loam and heavy subsoil. In those cases where the clayey subsoil extends to depths of several feet, no marked adverse conditions are apparent other than those usually accompanying rather dense, poorly structured subsoils. In certain other localities where coarse materials closely approach the surface or show a greater degree of cementation than usual deep-rooted crops do not give good results. A sandy phase of this type is recognized in the earlier detailed survey of the Red Bluff area. In many respects this phase represents a zone of material intermediate between the typical Kimball loam and the Tehama silt loam. It is not essentially different from the main type in its agricultural uses and possibilities.

*Location.*—The Kimball loam is encountered in many areas of rather general distribution in the upland plain west of the Sacramento River in the general region northward from Orland to the head of the valley. The type occupies elevations intermediate between the higher Redding and Corning series and the slightly lower Tehama and Elder series. The boundaries of areas of this type are somewhat indistinct in places, the soil grading into adjoining series. It is probable that a part of the region southwest of Woodland should be classed with this type rather than the Corning gravelly loam. In this locality certain low ridges and slightly elevated remnants of an earlier but now disappearing valley plain remain. These are included with the Corning gravelly loam, but the smoother areas which are rather low in gravel content, but have the reddish cast of the Corning series, might properly be classed with the Kimball loam. In the region just north of Stony Creek, within the limits of the previously surveyed Colusa area, this type includes the fine sandy loam and part of the loam types mapped in that survey under the San Joaquin series, now recognized as belonging properly with the Corning and Kimball series.

*Topography and drainage.*—The surface is gently rolling to level, with occasional small cuts or washes and a few local depressions. There is a slight tendency toward a hog-wallow topography in places, and under such conditions the Kimball varies from the San Joaquin series in no particular except the absence of an iron-clay hardpan. The ridges, hills, and steep slopes, so general in the Corning gravelly loam, do not appear in this type. The elevation and slope provide ample surface drainage, except in small depressed areas. Subsoil conditions frequently make percolation slow, but in general the type is well drained. It is mainly barren, an occasional scattered growth of upland oak being its only tree growth.

*Utilization.*—The Kimball loam is not extensively cultivated. Small areas are dry farmed to grain, but the yields are low. The type is rather poorly adapted to dry farming and attempts to produce fruit without irrigation have met with practical failure. It does not possess a subsoil of highly absorptive and retentive powers and requires irrigation for full development along all agricultural lines except grain farming. At one time the Kimball loam was much more extensively farmed to grain than now, but it is doubtful whether its present use will be much increased along any line until water is supplied. Some underground water for irrigation is available, particularly at points where the areas of lower elevation are near the river or its more important tributaries. The possibility of irrigating by pumping varies widely. The cost of obtaining water by pumping is great over the larger part of the type. The soil could be irrigated under an extensive gravity system.

With irrigation this type is best adapted to peaches, almonds, berries, olives, figs, and grapes. In addition, other crops which do not require a very deep friable soil and subsoil may be grown. Alfalfa, plums, and prunes do not do so well as the crops mentioned, but can be grown with some success on the deepest phases.

#### TUSCAN SERIES.

The soils of the Tuscan series are reddish brown and predominantly of loam or sandy loam texture with quantities of andesitic or basaltic gravel or roughly-rounded stones disseminated through the soil and scattered over the surface. So far as mapped, they are exceedingly shallow, and at shallow depths rest upon massive beds of firmly or partially indurated waterworn gravel with finer interstitial material, sometimes interbedded with deposits of a gray sandy nature, but nearly all andesitic in character and derived as a water-laid product from the volcanic tuffs and breccias giving rise to the soils of the Aiken series. The soil material of the Tuscan series is a weathered product derived from these old valley-filling deposits. They occupy extensive elevated, dissected, and excessively drained valley plains of arid, treeless character. The cemented substrata are relatively impervious to both roots and water, and over considerable areas are exposed or have only a patchy soil covering. The soils are untilled and are utilized for grazing. Some of the deeper phases having 2 or 3 feet of soil can be made productive, but irrigation is necessary.

#### TUSCAN STONY LOAMS.

*Description.*—The surface soil of the Tuscan stony loams as mapped in this area consists typically of about 12 inches of reddish-brown loam or sandy loam, slightly sticky and rather compact when dry. The loam and sandy loam types vary little except in texture, both having the same range in depth. Nearly everywhere over the surface

are quantities of rounded cobbles, occurring as an irregular, scattered covering, or as irregular strips occupying the bottoms of shallow depressions. These loose stones, all of andesitic or basaltic character, range in size from 3 to 14 inches in diameter, but near the areas of soils of the Aiken series they are sometimes accompanied by much larger and more numerous fragments and blocks of the same rock formations. In their disintegration the stones fill the soil material with quantities of small-sized subangular fragments. In small areas the soil has a depth of 18 to 30 inches, carries fewer rock fragments in the soil body, and is less burdened with the stony surface accumulation than is typical. Ordinarily, however, the soil is underlain at very shallow depths by masses of cemented waterworn gravel, sometimes roughly assorted and interstratified with beds of fine-textured gray material, often consisting of sand derived from rocks similar to those giving rise to the other material composing the mass. Numerous exposures along stream banks show the great depth and uniformly impervious character of this substratum.

The following table gives the average results of mechanical analyses of samples of soils of the Tuscan stony loams:

*Mechanical analyses of Tuscan stony loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Tuscan stony loam: 24179, 24180.....	Soil.....	<i>Per cent.</i> 4.0	<i>Per cent.</i> 6.0	<i>Per cent.</i> 4.9	<i>Per cent.</i> 11.8	<i>Per cent.</i> 20.0	<i>Per cent.</i> 30.1	<i>Per cent.</i> 23.1
Tuscan stony sandy loam: 24177, 24178.....	.....do.....	7.4	14.7	7.9	11.7	16.9	28.9	12.3

*Location.*—The Tuscan stony loams comprise a large total area in the northeastern part of the survey, extending from the head of the valley southeastward to Oroville in more or less continuous bodies. A few small areas occur farther south in the vicinity of Lincoln. These occupy a slightly more steeply sloping plain than the typical areas, are of even more shallow character, are underlain by andesitic tuffs and breccias, and upon the east merge with the soils of the Aiken series. This group of soils no doubt once occupied a much greater area than at present, the bodies which remain being but remnants which are even now disappearing to give place to the Vina series and other more recent soils. The large area commencing at the head of the valley and extending down its east slope in an almost unbroken manner to Chico includes the greater part of the group. The detached areas were probably connected at one time with the main group as now mapped. The group consists of elevated plain soils which are subject to destructive erosion. The region occupied by this group

was once an unbroken plain, but is now diversified by the erosion of streams through the larger bodies.

*Topography and drainage.*—The area occupied by these soils is bounded on the east mainly by the soils of the Aiken series, where rather abrupt ascents along regular lines lead up into the main bodies of the latter. From this boundary the Tuscan stony loams slope away to the westward as a plain having an average slope toward the river trough of about 50 to 60 feet to the mile (see Pl. I, fig. 1). In some areas there is a tendency toward a hog-wallow surface, and most of the sandy areas are slightly modified by wind. The lower boundary of the area covered by this group, along its contact with the recent alluvial soils of the valley trough, is usually very distinctly marked, very pronounced terrace lines prevailing for many miles. In other instances the elevated sloping plain of the Tuscan stony loams approaches the more recent soils by a gradually decreasing slope which finally merges into the flatter topography of the valley soils. Even here the soil boundaries are very distinct, although there may be margins of the higher plain irregularly modified to shallow depths, giving variations of the Vina series. An example of this is found east of Chico in certain parts of two bodies mapped as the Vina loams and Tuscan stony loams.

*Utilization.*—The group is entirely treeless in its typical occurrence and supports only a scant growth of grass, the larger areas being utilized mainly as sheep pasture. A few trees and brush sometimes fringe the waterways.

The Tuscan stony loams group is largely nonagricultural under present conditions. The shallow soils available for plant-root development and an unfavorable subsoil condition make it one of the poorest groups of soils of the area. Its general topography is favorable to irrigation, but little or no attempt has been made to irrigate these lands. The low state of development at this time, even of better types than this, makes its value low. There are patches and small bodies here and there which contain less gravel and stony material in the surface soil than typical. These often occupy slightly lower general elevations, and have received some transported material, increasing the depth of the soil. Unsuccessful attempts have been made to grow grain upon this deeper phase. The deeper soils are adapted, with irrigation, to stone fruits, berries, and certain other crops. Even alfalfa can be grown with profit upon the deeper phases, but the crop is short lived. Irrigation is the controlling factor in the development of this group of soils.

#### GRIDLEY SERIES.

The soils of the Gridley series are predominantly of reddish-brown color, with included bodies of rather light to dark brown color in which the reddish tint is less pronounced. The subsoils are similar

in color to the soil material or of slightly more reddish tint and are typically, as recognized in this area, without hardpan, though calcareous seams and incrustations approaching an incipient hardpan may occur. The series occurs over level to gently sloping or gently undulating valley plains including shallow depressions without drainage. Much of the series was originally covered with valley oak. The soils are derived from sedimentary old valley filling deposits which may in some cases have been modified by addition of later alluvial wash. Drainage is somewhat deficient during the rainy season and portions of the areas may at times be subject to overflow.

#### GRIDLEY LOAMS.

*Description.*—The Gridley loams consist mainly of loam and silt loam types, with minor inclusions of areas of slightly lighter or heavier texture.

The Gridley loam is of reddish-brown color, the reddish tint, however, not always being pronounced. The texture is that of a loam, which becomes quite sticky when wet. This material may extend through the subsoil to a depth of 6 feet or more, or may be underlain at a depth of 2 to 4 feet by a more reddish brown to lighter brown clay loam to loam. Thin crusts or seams of incipient hardpan formed by deposition of calcareous material and of iron salts occasionally occur but typically the type, as mapped in this survey, is without true hardpan.

The silt loam type is of smooth silty texture, sticky when wet but friable under cultivation. In color and character of subsoil it resembles the related loam type.

*Location.*—This soil group is confined to the eastern side of the valley, occurring most prominently in the vicinity of Wheatland.

*Topography and drainage.*—Drainage is usually fairly well developed, though during the rainy season the soils are wet and an excess of water may occur in the flatter areas and occasional bodies may be subject to overflow by flood waters of minor streams and drainage ways.

*Utilization.*—The soils of this group are devoted mainly to the growing of grains without irrigation. They are productive, retentive of moisture, and when irrigated are well adapted to a much wider range of general farm crops as well as fruits.

#### ANTIOCH SERIES.

The soils of the Antioch series are brown in color, and, as encountered in this survey, rather friable in structure. The subsoils are heavier in texture, yellowish brown in color, and often of a calcareous nature. The series occupies a steeply sloping to comparatively flat terracelike plain lying between the elevated soils of the Diablo series and tidewater level. Drainage is usually good except in a few flat

depressions, where a darker colored soil is encountered. These would have been mapped as Montezuma material had they been of sufficient size. The Antioch soils occur as alluvial or sedimentary deposits derived largely from soils and rocks of the Altamont and Diablo series and deposited when water levels were higher than at present, rendering them now subject to removal rather than to the process of formation. In this survey the series is inextensive. In addition to the areas mapped in the southwestern part of the survey, undifferentiated bodies occurring along the western border are included with the Antioch and Montezuma soils (undifferentiated).

#### ANTIOCH LOAM AND CLAY LOAM.

*Description.*—The Antioch loam to a depth of 20 or 30 inches consists of a brown, somewhat sticky loam which usually becomes slightly heavier with depth. The organic matter content is fairly high and the structure rather friable, which gives the soil good water-holding capacity and renders tillage easy. The subsoil is yellowish to brownish yellow, the latter color predominating, but a mottled effect is often noticed. Calcareous seams occur in the subsoil, but these have little effect other than to render it somewhat less friable in places. Coarse, gravelly material is occasionally found near the line of contact with the Diablo clay adobe.

The Antioch clay loam consists of a brown, sticky, clay loam having about the same depth as the loam. The texture becomes distinctly heavier in the subsoil, approaching a clay, but in other respects it is similar to the loam. A few small areas of dark-gray to black soil, usually occurring along regions of deficient surface drainage, would have been mapped as Montezuma clay adobe, if of sufficient extent.

*Location.*—These soils occur principally in one large body extending westward from Antioch in the extreme southwestern corner of the area. A smaller area is found at the southwest limits of the Montezuma Hills. Undifferentiated bodies occur in all areas of Antioch and Montezuma soils, undifferentiated.

*Topography and drainage.*—The soils of this series occupy a long, narrow plain which descends from an elevation of about 100 feet in the rolling hills occupied by the Diablo clay adobe to sea level at a distance of 1 or 2 miles. The topography is quite steeply sloping, but the lower margin of the plain approaches the marshy land by a gentle slope, merging here with the low-lying types of Muck and Peat or else extending to the water's edge. Some of the region near Antioch has a rolling topography, but most of it is but little diversified, except by streams issuing from the hilly region to the south and entering the group in deep channels. As these waterways reach the lower levels of the plain they become less accentuated and in the lower margin may appear as shallow washes.

Drainage is good, except in a few flattened depressions where water accumulates for short periods. Sufficient alkali to prevent the growth of crops is found in the area bordering the Montezuma Hills.

*Utilization.*—The Antioch loam and clay loam are naturally barren of trees and shrubs. Except for a few small orchards, mostly located upon the loam type near Antioch, these soils are only used for grain production or pasture.

#### ANTIOCH AND MONTEZUMA SOILS (UNDIFFERENTIATED).

*Description.*—The Antioch and Montezuma soils (undifferentiated) represent areas comprising small bodies of soil of the two series indicated, in such irregular occurrence that their differentiation upon the map is not practicable. For the most part, in the areas of this group, the two series are about equal in extent, and a detailed map outlining their occurrence would show them to be intricately associated. Some areas have the dark-gray or black soils of the Montezuma series, with all general features of subsoil and other characteristics as described under the Montezuma clay adobe, quite uniformly developed, and this type occupies most of that part of the group recognized as the Montezuma series. These darker colored patches generally occur on the gentle slopes or rounded ridges. The areas of Antioch material are largely of the Antioch loam and clay loam. In addition some of the higher crests and flats are capped with the Corning gravelly loam. These have contributed a color variation to the various soils lying around their margin.

*Location.*—This group of soils is encountered along the western margin of the survey, and the various bodies usually extend beyond the western edge of the area. There is one rather large body south of Winters and, continuing northward from the latter place, the group extends in successive areas to a point southwest of Williams. There is a rather large body west of Dunnigan, Zamora, and Yolo. Some of the lower rolling foothill country northwest of Willows no doubt comprises soils of this group, but the soils are classified as predominantly of the Altamont series.

*Topography and drainage.*—This soil group occupies elevated, rolling areas bordering the valley slope soils and leading back into the more elevated and diversified Altamont series of soils. These areas, as a rule, are sufficiently or even excessively drained, and south and west of Dunnigan some very steep hills and slopes occur. Nearly all of the group is capable of tillage, although contour plowing is often necessary. Rock outcrops or sharp topographic features along the ridge crests are rare, although the normally rounded surface is broken in a few places by exposures of partially consolidated sediments.

*Utilization.*—The soils of this group are treeless. They are used only for grain growing and pasture. Summer fallowing is generally practiced, and much of the grain is cut for hay. Where the irregular areas of Corning gravelly loam occur little cultivation is practiced. Some areas of greatest elevation and most rolling topography along the western margin of the survey are uncultivated. On the more uniform slopes, grain produces good yields, but for the group as a whole the average crop yields are low. Fruit growing is not important and there is little evidence that the soils are suited to fruit production other than mentioned elsewhere under the descriptions of the Montezuma clay adobe and the Antioch loam and clay loam.

#### FRESNO SERIES.

The Fresno soils are typically light gray, gray or brownish gray in color. They are encountered to a limited extent in this survey and sometimes exhibit a more yellowish cast, or in the poorly drained areas a darker gray cast, than typical of their broad occurrence in the San Joaquin Valley. The soils are free from gravel and are typically underlain at depths of less than 6 feet by light-gray or ashen-gray subsoils, which in this area vary somewhat from these colors. A layer of white or gray, rather impervious hardpan, which is at least in many cases calcareous, varying in thickness from a fraction of an inch to several inches, is usually found within 6 feet and often at a depth less than 36 inches. It is variable in character and often slowly softens under irrigation, but is impenetrable to the roots of growing plants in much of its occurrence.

The soils of this series occur as old alluvial or sedimentary deposits, derived probably from a wide range of rocks, but possibly largely from granites, since they rather uniformly occupy positions in the valley opposite that portion of the range largely occupied by these rocks. The areas are sloping to undulating and generally treeless plains, probably low, broad, old alluvial fans or river deltas. The lighter soils are frequently modified by wind action, but this does not appear in this area. The surface is sometimes rendered irregular by "hog wallows," wind-drifted ridges, or indistinct remnants of older stream channels. These soils are not overflowed in their typical occurrence elsewhere but are at times in this area. They frequently are poorly drained and subject to injury from seepage waters and alkali salts. Under favorable conditions of irrigation and drainage and where not underlain by hardpan too near the surface, they are utilized elsewhere for the production of a wide range of crops, but are largely useless in this area at the present time owing to the presence of alkali and to poor drainage.



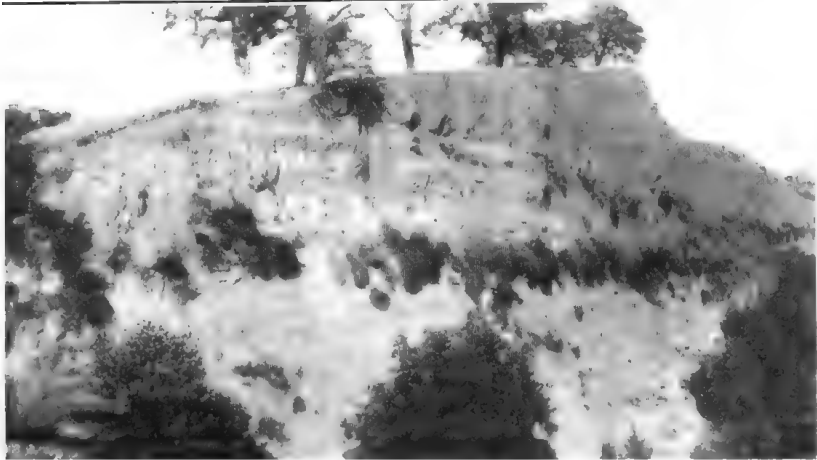


FIG. 1.—BLUFF AT FAIROAKS BRIDGE, SHOWING SECTION IN MATERIAL OF THE SAN JOAQUIN AND ARNOLD LOAMS, UNDIFFERENTIATED.

[Red hardpan substratum of the San Joaquin in upper portion underlain by gray beds giving rise to the Arnold below.]



FIG. 2.—A SUCCESSFUL SMALL ORANGE ORCHARD NEAR CORNING, TEHAMA COUNTY, ON SOILS OF THE CORNING SERIES.



## FRESNO LOAMS.

*Description.*—The Fresno loams vary in texture from a loam or fine sandy loam to a clay loam, the former predominating. The color of the loam is usually gray, sometimes with a yellowish cast, but the location of the type in a poorly drained region has tended to give it a rather darker color than is typical of the series where broadly developed, as in the San Joaquin Valley. At from 12 to 24 inches it may become yellowish gray or slightly brownish in color. The soil has a rather compact or even puddled structure with a medium to low organic-matter content. A gray or yellowish-gray calcareous hardpan, several inches or more in thickness, is usually found a short distance below the surface.

The clay loam of the group differs from the loam in having a higher humus content and occupying a slightly lower and more poorly drained position. Its texture is that of a sticky clay loam and approaches a dark-gray color where merging into the lower lying types to the westward. In other features it resembles the predominant loam.

The fine sandy loam occurs as an irregular strip bordering the contact of this group and the Hanford fine sandy loam to the eastward. It is slightly lighter colored than the loam, contains less humus, and is slightly better drained. The texture is that of an average fine sandy loam.

The group is free from gravel, boulders, or similar coarse materials.

*Topography and drainage.*—The Fresno loams occupy level or very gently sloping country intermediate between the lower extremity of the Hanford fine sandy loam delta on the east and the lower lying Muck and Peat or Sacramento clays of the basin region. Numerous small hummocks or "hog-wallows" characterize the surface, and the drainage is predominantly poor, owing to the slight slope and high water table, which cause the group to be flooded over a considerable part of its extent. The soils are affected with alkali. Even though drained and protected from overflow the type would contain enough alkali seriously to damage crops.

*Utilization.*—The entire group is untilled and is used only for pasture. Its present utilization must continue until drainage and reclamation from alkali have been effected. Salt grass (*Distichlis spicata*), the principal native grass, furnishes good pasture. The soils will be difficult to reclaim, but when thoroughly reclaimed they will grow a wide range of crops.

## MONTEZUMA SERIES.

These soils are typically dark gray to black, but as mapped in this survey include minor areas of brown soils considered as undifferentiated types of the Antioch series. The surface soils are clayey, yet friable and retentive of moisture. The subsoils are lighter colored, being yellowish brown or light brown. There is not much gravel present in either the soil or subsoil. Seams or nodules of calcareous nature characterize the subsoil, amounting at times to a noncontinuous hardpan. These soils are confined to the Montezuma Hills and along the western edge of the area. The surface is rolling to hilly, but without sharp features of rock outcrop and dissected drainage ways. The soils are the product of extensive, old deposits, probably of lacustrine character, and are now elevated above their former position.

The clay adobe is the only type of this series mapped in the area.

## MONTEZUMA CLAY ADOBE.

*Description.*—The Montezuma clay adobe is typically a very dark gray, or black, sticky, yet friable clay, manifesting all the tendencies to check and crack upon drying which are so characteristic of those soils having pronounced adobe structures. Although the color is prevailingly as stated, yet patches, streaks, and poorly defined small areas have a distinct brownish or dark-brown tint. The latter variations are often associated with lighter textured patches where the adobe structure is less in evidence. The soil continues to an average depth of 36 inches, where it grades rather sharply into a yellowish-brown or light-brown, rather compact, variably textured subsoil of clay loam, silty clay loam, or clay character. Occasionally layers of stratified more sandy and gravelly material occur, but the type normally has a heavy subsoil with pronounced moisture-retaining properties. Calcareous nodules, seams, and lenses are abundant in the subsoil, in some areas approaching a hardpan, which while not continuous or impervious influences subsoil percolation and the free penetration of roots. Calcareous concretions are often scattered over the surface. The humus content of the type is apparently high. The contact of this type with the Altamont soils exhibits gradational zones and the boundary is more or less arbitrary.

*Location.*—This type occurs in the southwestern part of the survey as a broad area coincident with the Montezuma Hills. It lies well out in the valley trough, the lower reaches of the Sacramento River encircling it upon the east and south.

*Topography and drainage.*—Although the surface is uneven with steep slopes, it presents a billowy, smoothly rounded appearance owing to the absence of sharp features of rock outcrop or dissected drainage ways. The extreme elevation is nearly 300 feet. This

characteristic topography continues throughout the hills, grading on the north through gentle slopes to the recent valley-filling material of the Solano series. The area is connected to the northwest with the low foothills of the Coast Range by a series of isolated knobs and ridges of residual material occupied by Altamont soils. While erosion is active, it proceeds uniformly and the absorptive powers of both soil and subsoil minimize run-off. The type is not excessively drained.

*Utilization.*—The type is treeless and practically all of it is cultivated, dry-farmed wheat being grown almost exclusively, with good yields until recent years, when they have declined. Irrigation will be necessary to develop intensive cropping upon this type and will have to be supplied largely by pumps.

#### ALAMO SERIES.

The Alamo series consists of dark-gray, drab, or black soils underlain by brown or reddish-brown subsoils. At depths of less than 6 feet a hardpan of red or mottled red, brown, and gray color is encountered. The hardpan occurs at an average depth of about 36 inches, but may be found from 15 inches downward. The cementing material consists predominantly of iron compounds. These soils usually occur in association with those of the San Joaquin and Madera series. As far as recognized in this area, only the heavier members of the Alamo series occur, the material being derived mainly from the associated series, transported and laid down under stagnated drainage conditions, and there modified by accumulations of organic matter resulting from the poor drainage and periodic overflows. The surface is relatively low, flat, and treeless.

#### ALAMO CLAY ADOBE.

*Description.*—The Alamo clay adobe consists of a dark-gray to black clay of an adobe structure. The soil is normally puddled and waxy when wet and after exposure during periods of drought checks and cracks into a mass of hard blocks and fragments. It is so intractable that good tilth is difficult to maintain. Its close association with the San Joaquin series of soils, as slightly depressed areas within or bordering the latter series, often gives rise to variations in color about the margins of the soil bodies. Slight knobs of the San Joaquin loams occur within areas of this type. The subsoil is usually lighter in color at 1 to 3 feet, where grayish or more often brown or reddish-brown colors prevail. The subsoil is often lighter textured than the surface soil and grades ordinarily at less than 4 feet into a rather impervious hardpan with iron compounds as the predominant cementing material. In many places, however, the hardpan is largely calcareous, closely approaching the Stockton clay adobe.

*Location.*—The type occurs in several small areas on the east side of the valley, being most extensively developed in the general region between Galt and Sacramento.

*Topography and drainage.*—The Alamo clay adobe occupies flat, poorly-drained depressions or low positions in the general region where the upland-plain soils merge with the lower lying basin or lowland types. In many instances it receives considerable run-off wash from minor streams. The surface is marked by winding, indistinct channels. Although it has poor drainage, the type is not usually affected by accumulations of alkali.

*Utilization.*—The type is ordinarily barren of tree growth. A part of it is farmed to grain and the remainder is used as pasture land. It is not adapted to any crop requiring a friable, well-aerated subsoil. Drainage, careful cultivation, and manuring are beneficial, and it is possible that figs and alfalfa can be profitably grown on the better phases. In a limited way possibly other crops, including bush fruits and vegetables, can be grown for local consumption with irrigation. Wherever uniform areas of sufficient extent occur, this type, like the Stockton clay adobe, is well adapted to rice culture, although not yet utilized for this purpose. Its physical features are such that only a small number of crops are possible.

#### SOILS FROM ALLUVIAL AND RECENT ALLUVIAL FAN DEPOSITS.

##### HONCUT SERIES.

The Honcut soils are prevailingly reddish brown, ranging to light reddish brown or brown. The subsoils are often slightly more reddish than the soils, and are of variable textures. Typically hardpan is not encountered within the 6-foot depth. Waterworn gravel is of infrequent occurrence in either soil or subsoil, but may be encountered in the vicinity of stream courses. These soils consist of alluvial deposits which occur both as alluvial bottoms and as alluvial fans, the former being subject to overflow. The material of the series in this area is derived largely through erosion from the old red valley-filling deposits giving rise to such soils as the San Joaquin or Redding, and from the rock and soil material of the Aiken series.

##### HONCUT LOAMS.

*Description.*—The Honcut loams include mainly the loam and silt loam, with small bodies of the fine sandy loam and clay loam of the Honcut series.

The Honcut loam usually consists of a reddish-brown, light reddish brown, or brown rather sticky loam from 24 to 48 inches in depth, sometimes even extending to 6 feet or more. The subsoil is generally a more reddish-brown or yellowish-brown clay loam. In places it

consists of a reddish or brownish friable loam. Waterworn gravel is sometimes encountered in the soil near the stream courses. In some of the smaller narrow bodies of this type and at points of contact with the series of hardpan soils, a hardpan development is encountered in places, but it is typically free from hardpan.

The Honcut silt loam is a light reddish brown or brown, smooth textured silt loam. The material is usually uniform in texture throughout the 6-foot soil section, but the subsoil is often lighter colored than the soil and may be even yellowish brown. A subsoil of clay loam or silty clay loam occurs in places somewhat removed from stream channels. In other respects, this type resembles the loam member of the series.

The Honcut fine sandy loam is of small extent. In the area bordering Dry Creek, extending eastward from Galt, a thin overwash of fine sandy loam overlies the Honcut loam, and in places the soil is predominantly a fine sandy loam to a depth of several feet, as along Dry Creek near the eastern edge of the area. The Honcut fine sandy loam merges with the loam and silt loam of this group, and differs from these types only in texture. In some phases it approaches the Hanford fine sandy loam, being underlain by alternating layers of variously textured material arranged in irregular order.

The Honcut clay loam is developed largely as local small areas. It frequently occupies the flatter areas of the region occupied by the Honcut loams.

This soil group, as mapped in this survey, includes the soils recognized in the earlier survey of the Stockton area as the Stockton loam and the Stockton silt loam.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Honcut loam:

*Mechanical analyses of Honcut loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
20720.....	Soil.....	0.6	3.9	2.9	13.4	14.0	46.8	18.5
20721.....	Subsoil.....	.3	1.7	2.5	14.6	23.3	37.9	19.8

*Location.*—Several areas of these soils are encountered on the east side of the valley between Honcut and the southern edge of the area. An important area lies along Honcut Creek, and Dry Creek is flanked for many miles by these soils. Areas of less importance occupy the alluvial bottoms of minor creeks throughout this region. In addition to this alluvial-bottom phase, there is an extensive area in the southeastern corner of the survey, occupying a broad alluvial fan.

*Topography and drainage.*—The stream-bottom phase of this group has a rather uniform surface, broken only by occasional gullies, the stream bed of the parent stream, or by shallow overflow channels. Most of the soil is adequately drained, but subject to occasional floods. The soils of the group are typically free from alkali.

The large area in the southeastern part of the survey occurs largely as a modified fan with a generally level, smooth surface traversed by a few streams or abandoned stream channels. This phase is not so subject to overflow as the bottom development, and has well developed drainage. It occupies a large alluvial fan within the region of Calaveras River and Mormon Slough, and while it is recognized that the material shows some departures in texture and slight variations in color from the typical, it is most satisfactorily classed with the Honcut series. The soils of the group are typically free from alkali.

*Utilization.*—This group of soils was originally forested with valley oaks and other trees, but is now mainly cleared, only occasional trees or groves remaining. Nearly all the Honcut loams are devoted to dry-farmed grains and are recognized as consistently good producers of these crops. Untilled areas afford excellent pasturage throughout the year or are cut for hay. As with most of the other good soils in the valley, the development of this group has been retarded by ownership in large individual tracts. The group is well adapted to fruits, alfalfa, and a great variety of crops, and where subdivided and irrigated is a valuable soil for a diversified agriculture.

The Honcut loams comprising the large area in the Linden region are excellent soils with crop possibilities equal to those of the Hanford fine sandy loam around Lodi. The Honcut loams, particularly in certain phases, as near Linden, are favorable to deep root development, the soil being many feet deep with no subsoil features to arrest root penetration. Some areas of the group are less valuable owing to the variable features of overflow, drainage, soil depth, and frost conditions which accompany the lower, irregular bodies.

#### VINA SERIES.

The soils of the Vina series are brown. The lightest textured members of the series are brown or grayish brown ranging to dark brown, slightly reddish brown or chocolate brown in the heavier types. The soils are friable, usually free from gravel, and are well drained. The subsoils are usually lighter colored, being light brown, slightly yellowish brown or a lighter shade of reddish brown. They are typically 6 feet deep but shallow phases are found where the cemented material of the Tuscan series occurs as a substratum at lesser depths.

This series is alluvial in origin, being deposited mostly as alluvial fans composed of material derived almost entirely from fragmental



andesitic tuffs and breccias, with smaller amounts from basalt. Overflow occurs in some parts of the fans but this is not serious. These soils are differentiated from the Sutter series by color.

#### VINA FINE SANDY LOAM.

*Description.*—The soil of the Vina fine sandy loam consists of a grayish brown or brown fine sandy loam of extremely friable structure. Typically it is the lightest colored member of the series. This type is in the main remarkably uniform, although there are small patches where the typical smooth fine sandy texture gives way to phases containing more silt or sand. It is usually free from gravel, except in narrow strips bordering washes, where coarser alluvium may be present. This is particularly true of some of the areas lying along Mill and Chico Creeks at points where they enter the valley and are closely bordered by soils of the Aiken and Tuscan series. The coarser material consists of subangular or rounded andesitic gravel. Slightly lighter colored subsoils may occur from about 36 inches downward. Ordinarily, the type as described extends to a depth of 6 feet, but occasionally gravel beds or the conglomerate substratum of the Tuscan series occurs at less depth. Some of the area just north of Chico approaches a light loam in texture. This type is easily tilled, never puddles or bakes, and absorbs and retains moisture well.

The following table gives the average results of mechanical analyses of samples of the soil of the Vina fine sandy loam:

*Mechanical analyses of Vina fine sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24137, 24138, 24139....	Soil.....	0.5	2.6	5.7	27.1	33.8	22.1	7.8

*Location.*—This type is rather extensively developed in the fan deltas of Deer and Chico Creeks, but small bodies occur in association with other soils of the same and Tuscan series from the head of the valley to the neighborhood of Chico. The boundary lines defining this soil are usually distinct where bordered by soils of the Aiken or Tuscan series, but gradations into other types of the same series are frequent.

*Topography and drainage.*—The surface of the Vina fine sandy loam is smooth, but with sufficient slope toward the main valley trough to give good drainage. It is often marked by gentle depressions, and irrigation in certain parts has rendered these old channel remnants rather poorly drained. Particularly is this true of the Deer Creek body above the point where it broadens into the alluvial delta at Vina. Portions overflow in time of highest water, but this is not a serious factor. On the whole, however, the type is well drained.

*Native vegetation.*—The type was originally forested but it is now cleared and used for agriculture. A few scattered valley oaks, with some willow, cottonwood, and grapevines along the stream ways remain.

*Utilization.*—The Vina fine sandy loam because of its depth, friable structure, natural fertility, and water-holding capacity is one of the most valuable soils in the area. It is all capable of irrigation and considerable development along this line has taken place. It is too valuable a soil for grain growing, although heavy crops are obtained from such parts as are not otherwise utilized. The soil is admirably adapted to alfalfa, maximum yields being obtained with irrigation. Peaches, prunes, almonds, olives, apricots, bush fruits, grapes, melons, and truck crops are all grown with success. Many of the orchards are poorly cared for and maximum profits are not made. With good methods of irrigation and under local climatic conditions this soil has as wide a crop range as any other soil in northern California.

#### VINA LOAMS.

*Description.*—The Vina loams constitute a group of soils ranging in texture from a rather silty loam to silt loam, the former predominating. The color is usually brown or slightly reddish brown, the latter being generally associated with the shallow phases of the group. The structure is friable, and on the whole the types are retentive of moisture and easy to till. At about 30 inches the color usually becomes a little lighter, and the texture continues to a depth of 6 feet. Gravel is usually absent, except in some portions of the shallow phase. Except for the larger amounts of silt present, the included Vina silt loam varies but little from the loam.

Although 6 feet is considered the minimum depth of the soils of this group, there are considerable areas of a more shallow character and lower crop value. The region occupied by this phase was at one time a part of an extensive plain, large portions of which are still occupied by the Tuscan series of soils. Mill Creek, a perennial stream, traverses this plain in a small valley until it reaches a point about 2 or 3 miles from the Sacramento River where the main waterway divides into several small channels, some of which are in present use and others abandoned. The shallow phase of the Vina loams occupies the slightly elevated V-shaped areas lying between the diverging channels. The soil usually consists of 20 to 36 inches of brown or reddish-brown friable loam. Generally it is here underlain at a depth of about 24 inches by gravel beds composed of reworked, transported material derived from the indurated subsoil of the Tuscan series. The subsoils often rest directly upon the undisturbed conglomerate substratum found beneath the Tuscan series. The shallow phase represents an intermediate condition

between the older Tuscan soils and the deep deposits of the typical Vina series. Small quantities of waterworn gravel, andesitic or basaltic in character, are usually found throughout the soil mass in the shallow phase. There are some areas of lesser importance near Chico that are similar to the shallow phase as mapped along Mill Creek. These usually occur as the eastward extension of the main type where it approaches the Tuscan series with decreasing depth.

The following table gives the results of a mechanical analysis of a typical sample of soil of this type:

*Mechanical analysis of Vina loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24143.....	Soil.....	1.4	2.8	3.6	12.5	19.1	45.8	14.8

*Location.*—The Vina loams are found in scattered bodies along the east side of the river from a point east of Red Bluff to a point a few miles south of Chico.

*Topography and drainage.*—The surface varies from nearly level to sloping. Drainage is good and no alkali occurs. The relative elevation of the Vina loams is often slightly higher than that of the heavier types which occur with it in the alluvial fans. The shallow phase is apt to occupy more pronounced elevations, often merging with the lower extensions of the Tuscan series of soils.

*Native vegetation.*—The native vegetation on the Vina loams is quite similar to that of the other soils of the series. The growth on the shallow phase about Mill Creek consists largely of upland oak, ceanothus, and a variety of shrubs.

*Utilization.*—The Vina loams constitute some of the best soils of the area and practically all of them, except portions of the shallow phases, have been utilized. They are capable of being brought into a very high state of cultivation under irrigation and produce heavy yields. The crop range indicated for the Vina fine sandy loam applies also to the group. The rather large body of Vina loams occurring about 3 miles southeast of Chico is partly utilized by Chinese vegetable gardeners and fruit growers. The Plant Introduction Gardens of the Bureau of Plant Industry of the United States Department of Agriculture are located upon this same area. A detailed examination shows that the gardens include various phases of the Vina loams and a smaller area of Vina fine sandy loam.

The shallow phase of the Vina loams does not have as high an agricultural value. However, certain portions of it are quite extensively developed by irrigation. It is best adapted to peaches, grapes, olives, figs, and bush and vine fruits. Alfalfa, plums, and pears

can be grown in a limited way where the soil is deep enough or where the subsoil is free from gravel. Citrus fruits may be profitably grown upon the deeper portions of this phase, where the local climatic conditions are favorable.

#### VINA GRAVELLY LOAMS, SHALLOW PHASE.

*Description.*—The soils of the Vina gravelly loams, shallow phase, are subject to considerable variation in texture, structure, and depth, but consists usually of brown or reddish brown loam of rather sandy or gritty texture, carrying a large amount of waterworn gravel similar to that in the bordering soils of the Tuscan series. The soil is loose, shallow, and poor in water-holding power. It usually passes into very gravelly beds of unconsolidated material or into the characteristic substratum of the Tuscan series at a maximum depth of 24 to 36 inches. The surface is often more or less strewn with angular rocks or boulders of andesite. In small areas the soil may be a gravelly sandy loam or fine sandy loam differing but little from the loam except in texture.

*Location.*—The soils of this group usually occur as narrow strips bordering small washes or intermittent streams traversing the Tuscan series or along the lower margin of the latter soils where they give way to the main soil bodies of the Vina series.

*Utilization.*—Association with large bodies of poor soils, lack of irrigation water, shallow character, and the narrow, irregular shape of the areas all combine to make the soils included under this head of little agricultural importance. Portions of the area covered could be intensively cultivated were irrigation water available. Parts of one or two fields of dry-farmed land occur upon this group, but at present grazing is practically their only use.

#### VINA CLAY LOAMS.

*Description.*—The Vina clay loams include the Vina clay loam and Vina silty clay loam types.

The soil of the Vina clay loam consists of a brown, dark-brown, or slightly reddish brown, very smooth textured clay loam. There is a slight tendency to puddle and crack in areas of sluggish drainage, but nearly all of the type is friable and with proper tillage acts like a much lighter textured soil. To a depth of 6 feet the texture and structure are rather uniform, but a change in color is usually noted at 24 to 30 inches. The subsoil as a rule is somewhat lighter in color, being slightly yellowish brown or a lighter reddish brown. Like the surface soil, it has good water-holding capacity and is a good medium for deep-root development. A few small waterworn andesitic gravel or gritty material may occur

throughout the soil mass, but rarely in quantities sufficient to affect crop values. In a few instances cemented beds representing the substratum of the Tuscan series occur at a minimum depth of about 5 feet, but these do not affect the agricultural value of the type.

The Vina silty clay loam does not vary essentially from the clay loam member, except in texture.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Vina clay loam:

*Mechanical analyses of Vina clay loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24144, 24146.....	Soil.....	0.4	1.0	1.4	7.3	22.3	47.9	19.2
24145, 24147.....	Subsoil.....	.2	1.2	1.7	8.4	20.4	46.4	21.1

*Location.*—The Vina clay loams extend from a point midway between Oroville and Chico northward along the east side to the head of the valley. They usually occur in rather large tracts constituting a part of the broad alluvial fans deposited by the various creeks as they emerge from their small canyons and flow to the valley trough through dividing channels.

*Topography and drainage.*—The Vina clay loams occupy an elevation intermediate between the lower-lying Columbia and Stockton series of soils and the higher-lying soils of the Tuscan and Aiken series. They are rather easily separated from neighboring types of other series, but merge with types of the same series. The surface is smooth or, as in case of the delta of Chico Creek, marked by slight stream-built ridges, with accompanying shallow abandoned waterways. A flatter phase is developed in localities lying between Los Molinos and Copeland, and in the general region of Cana. The soils here are formed by many intermittent streams or gulches which emerge from the Tuscan series. In such localities the areas are subject to occasional overflow, but this condition is exceptional, the soils as a whole being well drained yet retentive of moisture.

*Native vegetation.*—This soil group originally supported a variety of trees, valley oak predominating. It is now cleared and produces a wide range of crops.

*Utilization.* The greater part of the Vina clay loams is used for grain growing, but eventually it will be intensively used for the production of many fruit and truck crops. Present grain yields are heavy. In the vicinity of Los Molinos where irrigation is practiced indications are that the type is well suited to alfalfa, many fruits, and a great variety of general farm crops. A dry-farmed almond

industry has been built up on this group to some extent in the vicinity of Durham and Chico. Although the soils included within the group are well adapted to dry farming methods, and much has been done along this line, their full value can not be realized without irrigation and the subdivision of larger tracts into small farm units. On the whole, it is one of the best group of soils in the area and practically its entire extent is capable of utilization for small farms wherever irrigation is practicable.

#### VINA CLAY ADOBE.

*Description.*—The Vina clay adobe is typically a very dark brown or chocolate brown heavy, sticky clay of pronounced adobe structure. It is hard and compact when dry and shows a great deal of cracking and checking. At an average depth of about 30 inches the color becomes lighter, the material passing into compact brown clay loams or clays not unlike the subsoils of the Vina clay loams. The subsoil is not usually calcareous, but may be along its contact with the Stockton clay adobe. The entire soil section is free from coarse material yet the type is more absorptive of moisture and gives it up to plants better than similarly textured soils of poorer granulation, such as the Willows clay. Typically gravel beds or indurated layers are absent within a depth of 6 feet, but a distinct phase of considerable extent is found which is shallow and much lower in agricultural value than the main type. This phase is closely associated with the Tuscan series of soils. It may occur within the more elevated Tuscan plain as a poorly defined alluvial product or overwash derived largely from the still higher lying soils of the Aiken series, such as the area lying several miles north of Los Molinos. The slopes of this area are marked by many small drainage ways, sometimes definite water channels, but usually occurring as ill-defined, meandering depressions without abrupt banks. These depressions contain great quantities of roughly rounded andesitic or basaltic cobbles from 3 to 8 inches in diameter. The adobe material at this point usually does not have a depth of more than 20 to 48 inches, passing abruptly into the indurated mass of gravel which underlies the Tuscan series, so predominant in that locality. In fact, that portion of the shallow phase of the Vina clay adobe which lies within the upland plain of the Tuscan series and at about the same elevation may contain isolated knobs of the latter series. Southeast of Chico several patches or long narrow bodies of Vina clay adobe are bordered or nearly surrounded by the Tuscan series. These areas are often very shallow, especially along contact with the Tuscan series, but may broaden out downstream, finally developing within short distances into the deep, typical soil of the main type.

The following table gives the average results of mechanical analyses of samples of the soil of this type:

*Mechanical analyses of Vina clay adobe.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24148, 24149.....	Soil.....	1.5	2.6	2.2	4.3	9.0	33.3	46.9

*Location.*—The most typical areas of this type occur in the vicinity of Chico. Numerous small scattered bodies are also shown within areas of the Vina clay loams. The main body of the shallow phase is found to the north of Los Molinos.

*Topography and drainage.*—This type normally has rather poor drainage. It often occupies the smoother outer portions of the alluvial fan deltas as the regional slope diminishes to the westward and gradually merges with the southward sloping valley trough. The surface is marked by small drainage ways or disappearing remnants of these, being a portion of the bifurcating distributaries traversing the alluvial fan. Most of the type may be overflowed for short periods during the rainy season. The shallow phases of the type usually have a steeper slope, resembling that of the Tuscan series. Subsurface drainage is sufficient to prevent the accumulation of alkali.

*Native vegetation.*—The shallow phase of the type associated with the upland plain is treeless, and has a generally barren appearance. Typical bodies, however, supported a timber growth, but of a less vigorous character than that on the lighter textured types of the same series.

*Utilization.*—The Vina clay adobe in its typical development is practically all used for grain growing, good yields being secured. Where irrigated and carefully handled the production of alfalfa is possible, but it may not be so profitable as upon the lighter members of the series. A few of the hardier fruits may be grown with moderate success. Several patches of very poorly drained character within the main type, together with practically all of the shallow phase, have never been farmed. The shallow phase is a poor soil owing to its shallow depth and excessive stone content and, together with the Tuscan stony loams of the same region, is used for grazing. The crop possibilities of this type are not so great as for the lighter soils but with proper management under irrigation the typical Vina clay adobe will prove quite a valuable type for certain diversified crops.

## WILLOWS SERIES.

The soils of the Willows series range in color from brown to reddish brown or dark chocolate brown and are usually free from gravel. The subsoils are light brown, reddish brown, or yellowish brown, occa-

sionally mottled with gray, may carry lime and gypsum, and are generally more compact and impervious than the subsoils of the Yolo series. They are alluvial in origin, being derived mainly from calcareous shales and sandstones, and influenced at points by material eroded from marginal valley deposits of unconsolidated old valley filling character. The series occurs along the stream courses and broad alluvial fans of minor intermittent foothill streams which traverse the valley slopes and plains. The surface ranges from gently sloping to flat. The heavier members of the series are often poorly drained, are sometimes subject to overflow, and may contain injurious amounts of alkali. In places the soil material has been modified by water from overflow basins or deposited in intermittent lakes.

WILLOWS FINE SANDY LOAM.

*Description.*—The Willows fine sandy loam is variable in texture. The surface material usually consists of a fine sandy loam occasionally approaching in texture a coarse sandy loam, underlain by sandy loam or strata of a silty or sandy nature. The average of the section to a depth of 6 feet is usually fine sandy loam. Gravel may occur at variable depths. A small percentage is frequently present near the surface and at 4 feet in depth the soil may rest on thick strata of sand and gravel. The color of the soil is usually brown, or when dry a grayish brown. The subsoil is typically of a lighter brown or yellowish brown color.

In this survey the Willows fine sandy loam includes the type previously mapped as Arbuckle fine sandy loam in the Woodland area, which is now recognized as a member of the Willows series.

The following table gives the results of mechanical analyses of samples of the soil and subsoil:

*Mechanical analyses of Willows fine sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
21152.....	Soil.....	0.4	5.8	10.6	33.3	20.5	17.1	12.1
21153.....	Subsoil.....	.0	4.1	8.5	32.7	25.4	18.4	11.0

*Location.*—Several square miles of this type occur south of Williams.

*Topography and drainage.*—The surface is quite uniform and well suited for irrigation. Drainage is good.

*Utilization.*—The type when irrigated will produce a rather wide range of crops, including alfalfa, grapes, almonds, peaches, figs, bush and vine fruits, and a variety of truck crops.



## WILLOWS LOAMS.

*Description.*—In the Willows loams are included the clay loam, silty clay loam and loam types of this series.

The Willows clay loam is the most extensive type of the group. It consists of a brown, chocolate brown or slightly reddish brown, clay loam, fairly friable when properly cultivated but inclined to be compact when not. On the more elevated portions of the type along small streams the soil is more friable than typical. In the flatter areas the soil may crack or check upon exposure. The soil averages about 36 inches in depth where it grades into a yellowish-brown or lighter brown subsoil of clay loam or clay texture.

The Willows silty clay loam in its typical development consists of a compact, sticky, silty clay loam, free from gravel, and of about the same color as the clay loam member. It is of small extent.

The Willows loam consists of a light reddish brown or brown, friable loam. At times the content of coarse sandy material in the surface foot is sufficient to give a sandy loam. The soil may be 6 feet deep, but usually at 10 to 36 inches grades into a yellowish-brown or light-brown clay loam. The subsoil is occasionally a sandy loam in texture. The type is in general easily cultivated, both soil and subsoil being favorable to the growth of deep rooted plants.

The soils of the group are free from gravel and only rarely are appreciable amounts of coarse sand encountered. Hardpans and semi-cemented layers are also absent. The area between Madison and Winters is composed partly of clay, but varies little in general features from the rest of the group.

In the northwestern part of the previously surveyed Woodland area are included the greater part of several types formerly mapped as members of the Arbuckle series, but which are now recognized as Willows material.

Mechanical analyses of samples of the soil and subsoil of the Willows loams follow:

*Mechanical analyses of Willows loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Willows clay loam:								
15351, 16801.....	Soil.....	0.0	0.6	0.8	7.8	8.7	53.5	28.5
16802.....	Subsoil....	.0	.2	.6	9.8	5.7	67.2	17.0
Willows silty clay loam:								
15352, 16797.....	Soil.....	Tr.	.2	.1	.9	10.1	60.9	27.0
16798.....	Subsoil....	1.4	1.7	.7	4.2	1.4	66.4	23.4
Willows loam:								
16325.....	Soil.....	.0	1.7	4.0	25.6	11.0	35.8	22.5
16326.....	Subsoil....	.0	1.8	2.2	21.0	9.9	38.3	26.2

The following samples contained more than one-half of 1 per cent of calcium carbonate ( $\text{CaCO}_3$ ): No. 16797, 3.3 per cent; No. 16798, 3.6 per cent.

*Location.*—The Willows loams are found in extensive bodies of irregular occurrence from the vicinity of Germantown to near Arbuckle. Smaller areas, such as that north of Winters, are located elsewhere in the plains of the west side.

*Topography and drainage.*—The Willows loams occupy low ridges along stream courses or broad slightly elevated slopes which have been built somewhat above the surrounding country. Some of the soils of the group, however, occupy nearly flat depressions in the valley plain, but with this exception the soils have a good surface slope and rather good drainage. Alkali is not a factor, except in very localized areas.

*Native vegetation.*—The Willows loams are usually treeless.

*Utilization.*—The soils of this group are almost entirely devoted to grain farming, yields well above the average being obtained. Some of it is in pasture. The higher and better drained areas having a more friable soil are particularly productive and are considered the most important lands included in the survey. In a few favorably situated localities alfalfa and grapes are successfully grown without irrigation. The soils of the group are naturally rather retentive of moisture, but irrigation seems necessary for the best results with diversified crops. The soils are believed to be well adapted to a wide range of crops, including many tree fruits, and wine, table and raisin grapes. Vineyards of raisin grapes have been planted in a small way with good results. Alfalfa, bush fruits, and general farm crops, in addition to the crops mentioned, can also be grown upon the soils of this group, and when well watered they should eventually be capable of maintaining an intensive system of agriculture in small tracts.

#### WILLOWS CLAY.

*Description.*—The Willows clay varies considerably in depth, color, texture, and structure, and is a rather indefinite type, merging imperceptibly into the adjacent soil types. It consists, typically, of a slightly reddish brown or yellowish brown, very compact, rather impervious, tenacious clay which puddles when wet and bakes hard and checks when dry. The immediate surface at times has a pronounced light reddish or yellowish cast, but when plowed and cultivated a brown color, characteristic of the Willows series, is usually developed. An appreciable quantity of sandy material is sometimes found upon the surface, in places amounting to a patchy covering of sandy loam. The soil often extends to a depth of 6 feet or more, but frequently at about 3 feet material of yellower color and lighter texture is encountered. A mottled appearance sometimes characterizes the subsoil. From 3 feet downward calcareous concretions or thin lenses of soft hardpan may be found, but a true hardpan does not exist. The clayey character of the soil extends to a depth of many feet.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of this type:

*Mechanical analyses of Willows clay.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
16814.....	Soil.....	0.0	0.3	0.3	2.5	9.0	48.6	40.1
16815.....	Subsoil.....	.1	.4	.3	2.8	2.5	57.0	36.6

*Location.*—The Willows clay occurs in extensive bodies lying to the south and southeast of Willows. Smaller areas are found about Colusa Junction and for several miles southward.

*Topography and drainage.*—The type occupies nearly level, treeless, valley plains, and depressions or troughs of deficient or arrested drainage. During the winter or rainy season it is overflowed by intermittent streams and by the drainage water from the more elevated adjacent soil types. The surface is dotted by shallow depressions, the sites of intermittent lakes following the rainy season. Waterlogged soils and subsoils may occur for considerable periods.

*Alkali.*—Practically the entire type contains injurious accumulations of alkali, special reference being made to this in the chapter on Alkali. Salt grass and similar plants usually accompanying alkali conditions constitute the vegetation.

*Utilization.*—Most of the type is devoted to grazing, but near the borders where alkali is not present in excessive amounts, grain is grown with moderate yields. Much success is being had in reclaiming portions of this type by copious irrigation with water pumped from the deep substrata. Considerable alfalfa is being grown and it is possible that the entire type will eventually be utilized for tilled crops. When so reclaimed, the range of crops may be extended to include sorghum, and a number of other forage crops, but the type will always be restricted to a narrow range of crops owing to its adverse surface and physical characteristics.

WILLOWS CLAY ADOBE.

*Description.*—The Willows clay adobe presents some variations but it usually consists of a slightly reddish brown, dark-brown, or chocolate-brown clay with an adobe structure. It may at times be 6 feet deep, but usually at about 3 feet it becomes a light-brown, yellowish-brown, or yellow clay. The soil is usually free from gravel, except at the margins of foothills and foothill streams. When wet it becomes exceedingly sticky and puddles easily. Upon drying it exhibits a typical adobe structure, the soil cracking and checking until it is reduced to a granulated mass. Both soil and subsoil have

a high water-holding capacity and when properly cultivated are capable of retaining much moisture. The subsoil is typically quite compact and may be slightly calcareous. A phase of the type occurs in which the soil has a less pronounced adobe structure and the subsoil may be no heavier than a clay loam.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of the Willows clay adobe:

*Mechanical analyses of Willows clay adobe.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
15350, 16807, 16810.	Soil.....	Tr.	0.4	0.5	4.2	10.5	45.9	38.4
16808, 16811.....	Subsoil.....	0	.3	.4	2.6	5.1	41.5	50.1

*Location.*—The Willows clay adobe is one of the most extensive soil types of the west side valley plains extending from north of Madison to the vicinity of Lyman. Some bodies of lesser importance are found elsewhere on the west side. Indistinct soil boundaries usually separate it from neighboring types.

*Topography and drainage.*—The type occupies areas in local draws or depressions in the valley plain, or much more uniform and extensive areas covering the valley plain from the foothills to the valley trough. It is often found on the lower elevations of the plain as it approaches the outlying basin region flanking the Sacramento River. The general topography is slightly undulating or more frequently quite level. The surface is often flat or depressed and in such places drainage is deficient. It is generally treeless, except in the immediate vicinity of stream channels.

*Alkali.*—Alkali is usually found in injurious quantities in the poorly drained areas but the more elevated slopes are generally free from it.

*Utilization.*—This soil is devoted almost entirely to dry-farmed grain, but alfalfa is occasionally grown without irrigation. The higher and more extensive bodies are very productive and a small area is receiving some development through irrigation by pumping and gravity canals. The topography is favorable for irrigation and when this is supplied the high and well-drained areas will be adapted to many additional crops, including alfalfa and other hay and forage crops. Although the type is very clayey, it has a friable structure and is easily cultivated.

#### MADERA SERIES.

The soils of the Madera series are brown, the lighter textured soils being light brown or grayish brown, while the heavier often range to reddish or chocolate brown. The subsoils are usually reddish brown

or even red and are heavier in texture than the soil. At varying depths less than 6 feet the subsoil gives way to red or mottled red and gray iron-clay hardpans, with frequent seams of calcareous material. The cemented beds vary widely in character, being sometimes quite soft and permeable, or approaching a condition similar to the more impervious hardpan of the San Joaquin series. The soils are differentiated from the latter series, however, by differences in color, usually by a less pronounced "hog-wallow" surface, a deeper covering of soil over the hardpan, and by the fact that it usually represents a more recent alluvial product. The surface is level to sloping and better subsurface drainage prevails in this series than in the San Joaquin. The soils are usually alluvial, and are often closely associated with the last-named series.

#### MADERA LOAMS.

*Description.*—The Madera loams include the loam and sandy loam members of the series.

The Madera loam consists of a brown, light-brown, grayish-brown, or reddish-brown rather friable loam. Along its contact with the soils of the San Joaquin series a rather reddish brown phase is found. The prevailing texture is that of a loam, free from gravel, but often appreciable quantities of relatively coarse gritty particles are found. The humus content is low, but slightly higher than in the San Joaquin soils. The soil is usually easily tilled and is absorptive and retentive of moisture. The soil is usually inclined to become slightly heavier and redder with depth, and between 14 to 30 inches it passes into rather sticky, heavy loams or clay loams. At depths of less than 6 feet this subsoil material is underlain by red or mottled gray and red iron-clay hardpan, with frequent seams of calcareous material. The cemented layers vary greatly in color, thickness, and relative degree of induration, but the soil typically has a hardpan sufficiently dense and near enough the surface to impair its agricultural value. In the shallowest areas the hardpan may render the type not essentially different in its moisture holding capacity and depth of soil from the shallow phases of the San Joaquin series, but normally it lies at greater depths in the Madera than in the San Joaquin soils. In the better areas the hardpan consists of semicemented clay or sandy material lying at depths of 5 or 6 feet. The loam type comprises the greater part of the group.

The Madera sandy loam consists of a friable sandy loam having the same variations of depth and color as the loam. Usually, however, the soil is of a more grayish brown or lighter brown color. This is especially true of the area lying southeast of Marysville. Here the hardpan is unusually deep or may be lacking within 72 inches. This type is not very extensively developed in the area covered by this survey.

Local areas with a fine sandy loam texture occur to a limited extent as do areas having a clay loam texture; the latter are only slightly developed and most of them are included in the group of Madera clay loams.

*Location.*—The Madera loams occur in many small to extensive bodies scattered along the east side valley slopes from the vicinity of Honcut Creek southward to the limits of the area. In general, their distribution is coextensive with the San Joaquin series, and the plains occupied by the latter soils are frequently marked by strips of Madera loams or have considerable areas developed about their lower margins at points of mergence with the lower-lying soils of the main valley trough. The largest bodies of the group lie westward from Elk Grove and Galt and south and southeast from the latter place. Some of these areas were rather arbitrarily separated from the San Joaquin series on the basis of color, depth to hardpan, and general absence of well-developed "hog wallows."

*Topography and drainage.*—These soils occupy level, gently sloping or slightly rolling surfaces, being usually associated with the rather recent alluvial activities of minor streams. The tendency to form "hog wallows" with inclosed minor depressions is much less pronounced than on the San Joaquin series, but these features are nearly everywhere present to some extent. During the rainy season drainage is better than on the San Joaquin series, owing largely to the more pervious subsoils and better subsurface percolation. However, saturated or boggy conditions may be developed during periods of heavy precipitation. On the other hand, the Madera loams with their deeper soil covering resist drought better than do the San Joaquin soils. They are normally free from alkali. Some portions are overflowed during the rainy season.

*Native vegetation.*—The Madera loams are mostly cleared, but a scattering growth of valley oak remains. In many instances the boundary between the soils of the two series is along a general line marking the occurrence of timber upon the Madera series.

*Utilization.*—The Madera loams are mostly devoted to dry-farmed grains under a system of summer fallowing. The average yields for these soils are higher than for the San Joaquin series and in general they are better agricultural soils. Some orchards and vineyards are maintained on this group without irrigation, but this is possible only upon the best phases, and low yields are the rule. Irrigation is being supplied on representative bodies of this group by pumping and gravity canals, and a wide crop range is possible. The soils appear to be adapted to the same crops as the San Joaquin loams. However, alfalfa is better suited to the Madera loams than to the latter series, and in general heavier yields can be expected of all crops, owing to the deeper root zone and higher humus content.

## MADERA CLAY LOAMS.

*Description.*—The Madera clay loams include the clay loam and silty clay loam types of the series.

The Madera clay loam prevailing consists of a brown or reddish brown, rather sticky, puddled refractory clay loam, often manifesting a tendency to crack upon drying. This type varies considerably in depth, but usually grades at from 10 to 30 inches into a rather red, compact clay loam or clayey subsoil, of a few inches thickness. This clayey material rests in turn upon variable hardpan, ranging from a mottled red and gray semicemented bed to a distinctly red, highly indurated, true hardpan, of iron-clay character. In exceptional cases the soil is 6 feet deep without either semicemented or indurated layers, but the type as a whole possesses layers sufficiently cemented to interfere with the passage of both roots and water. Under moist conditions it is sometimes rather easily penetrated with a sharp soil auger, but at other times it is hard and impenetrable in character. Departures from the typical color often occur in poorly drained areas. Here the soil is gray and of a very sticky adobelike character. The type, as it usually occurs in this area, is rather more difficult to till than in other areas. When wet it is often miry and when dry very hard. These extreme conditions, however, do not exist over much of the body east of Nicolaus where rather better drained and aerated soils are the rule. The same may be said of some of the Marysville areas and of other higher and better drained sections. The type reaches its maximum value in areas having the clay loam surface soils underlain by rather permeable subsoils and without hardpan in the surface 6 feet, but this condition is not regarded as typical.

The Madera silty clay loam as recognized in this survey is a minor member of the group. In general it is similar to the clay loam type in color, depth, and hardpan features, but the relative elevation is slightly higher and the drainage better. A more friable structure also makes tillage easier than on the clay loam.

As mapped the soils of this group include the greater portion of the types mapped in the earlier Marysville area as the Alamo clay loam adobe and Marysville silt loam but which are now recognized as belonging more properly to the Madera series.

*Location.*—Most of the Madera clay loams are included in three bodies, one near Nicolaus, one extending north from Marysville, and another bordering Feather River. Several other small areas are found also in this general region. These soils are not bounded by distinct lines of demarcation, but usually merge imperceptibly into contiguous types.

*Topography and drainage.*—The surface is rather flat and drainage is usually poor. Low puddled areas alternating with slightly higher

portions give the surface a mottled appearance. Much of the soil occupies rather low positions and is undergoing more or less modification in color and texture, caused by standing water or by thin surface deposits of alluvial wash. Small drainage ways enter the soil bodies and in some instances an entire area may consist of small, poorly drained depressions. "Hog-wallow" conditions often prevail and smaller areas of inclosed San Joaquin loam are recognized. Much of the group is overflowed during the rainy season, or forms a collecting place for the run-off from nearby areas.

*Utilization.*—The types included in this group are treeless. The more poorly drained portions are used for pasture. As mapped, however, the group includes some very good land, which is utilized for grain production. Much of the soil will have to be drained and protected from overflow before it can be farmed. There are considerable areas now well suited to alfalfa, grapes and stone fruits whenever irrigated. These crops are at present grown in a limited way where the natural drainage is good or where improved by artificial means. Scattered plantings show that in addition to the above crops, figs, sugar beets, bush fruits, beans, and sorghum can also be grown.

#### MADERA AND GRIDLEY LOAMS (UNDIFFERENTIATED).

*Description.*—The Madera and Gridley loams (undifferentiated) include the undifferentiated loam and sandy loam, and fine sandy loam types of the Madera and Gridley series. Of these the loams are by far the most extensive.

The Madera and Gridley loams consist of a reddish-brown or light reddish brown loam, underlain by a somewhat redder brown, slightly sticky clay loam. The soil is usually free from gravel. Variations are occasioned by the occurrence of undifferentiated phases of a silty loam in very small areas. The soil is nearly always friable and easily tilled. As the southern boundary of the area covered by this soil group is approached, the texture becomes finer, these soils finally passing into the heavier types of a little lower elevation. Some of these areas occurring as remnants surrounded or bordered by the Stockton clay adobe are modified by and have subsoils much like the latter type. These soils usually have a noncontinuous hardpan within a depth of 6 feet. This frequently occurs within 18 inches of the surface, and over large areas has an average depth of about 3 feet. The hardpan, however, is an inconstant feature and is entirely absent, at least in the surface 6 feet, in important areas. The hardpan-free portions are in this survey recognized as Gridley material, the remainder as Madera. Hardpan-free areas occur along the Feather River, in Sutter County, and east of Feather River, north of Marysville.



The Madera and Gridley sandy loams consist of 30 inches to 6 feet or more of reddish-brown sandy loam, frequently containing fine, waterworn gravel. This is underlain by a dark-brown, sticky loam. Hardpan does not occur in these types except in an area east of Sutter where a calcareous hardpan is encountered at or below a depth of 4 feet.

The Madera and Gridley fine sandy loams do not differ greatly from the Madera and Gridley loams, except in texture. Important areas are found southeast of Gridley.

The hardpan layer in these soils is variable, being in places a thin stratum of easily fractured gray material, usually high in calcium carbonate. In other places it is a very thick, cemented mass, lying near the surface. In still other places it is a semicemented mass of mottled grayish and reddish-brown color. The hardpan has a direct and important influence upon the crop value of the soils of this group. As a whole they are friable, easily tilled and retentive of moisture.

*Location.*—The Madera and Gridley loams (undifferentiated) are extensively developed from near Biggs southward to the vicinity of Marcuse. They include the principal soils of this region, and in addition are developed in a smaller way east of Feather River opposite the main body. There are also two or three areas within the large body of the Stockton clay adobe north of the Marysville Buttes. The soils are not typically developed in these places.

*Topography and drainage.*—Broadly, this soil group occupies an extensive level plain, but the surface is slightly uneven, being marked by numerous shallow depressions without drainage outlets. Where other soils occur between these types and Feather River, there is usually a well-defined terrace lying a few feet above the river bottoms. Slight depressions and elevations occur where the soils merge into the Stockton clay adobe on the west, and gradation zones occur at their contact with most other types. Aside from the drainage afforded by Gilsizer Slough and one or two poorly defined drainage ways, the main body of this group is without any natural surface drainage. The movement of water is largely into the subsoil, and this is often hindered by the hardpan. As a consequence, the plain is dotted during the rainy season with numerous shallow bodies of water. A large part of the area occupied by this group is subject to overflow through the breaking of the Feather River levees, which frequently occurs in the southern extension of the main body. The flooding of this area ordinarily does not result in serious injury, as little sandy material is deposited and most of the water drains away rapidly. The sandy loam members are usually somewhat better drained than the other members of the group.

*Utilization.*—An extensive growth of oak once covered this entire group of soils, but this has largely been removed. The greater part of these soils is used for the production of grain, and they are considered well suited to such crops. They are also used to some extent for pasture, but both these uses are rapidly decreasing with the extension of more intensive agriculture. Much of the area has already been converted into orchards and vineyards and the prevailing large land holdings are being broken up with increasing settlement of the region. It has long been known that the soils of the group were valuable for fruits and alfalfa, but the development of farming along these lines was prevented by the control of the land in large individual holdings, lack of an active demand for small tracts, and the absence of easily available irrigation water. The land is now being sold in small tracts. Irrigation water is provided by both pumping and gravity systems, with a consequent rapid increase in the acreage planted to fruits, grapes, and alfalfa. The entire area occupied by the Madera and Gridley loams (undifferentiated) is well adapted to fruits, but differences in texture, drainage, and hardpan conditions influence the localization of such crops. Peaches have proved quite profitable. While the fruit thrives on a large part of the area, it does best where the soil is lighter. Many other fruits do well on those soils. Almonds and apricots make a good growth, but in many instances are not so profitable as in other parts of the survey. The Thompson seedless grape is successfully grown in many places on these soils, and many other varieties of grapes, including the Tokay, Mission, Zinfandel, and Sultana, do well. Alfalfa has been extensively planted and does well, but the yields vary with the differences in subsurface features. Yields are high except where the subsoil is heaviest and the hardpan rather close to the surface. Good yields of figs, especially the white Adriatic, are obtained.

The Madera and Gridley loams (undifferentiated), everything considered, is one of the better groups of soils in the survey, their rather mellow texture and warm nature making them well adapted to a diversified intensive agriculture. Some of the undrained depressions are a serious inconvenience to the growing of fruits and alfalfa, but it is entirely possible for them to be reclaimed by surface drains at moderate cost. It can be safely predicted that this soil group will continue its rather rapid development until practically all of it is in small farms, devoted to the production of many fruit and truck crops.

MADERA AND GRIDLEY CLAY LOAMS (UNDIFFERENTIATED).

*Description.*—The Madera and Gridley clay loams (undifferentiated) comprise the silty clay loam and the clay loam types of the Madera and Gridley series.

The silty clay loam material consists of 24 inches to 6 feet or more of a reddish-brown or brown, sticky silty clay loam. The soil is compact in places, with slight adobe tendencies, although the more silty phase is rather friable. The better-drained areas are not very difficult to till, but the depressed bodies are soggy and unproductive under present conditions. Subsoil conditions are variable, but gray semi-cemented beds often approximating well-cemented calcareous hardpan occur at an average depth of about 30 inches. This hardpan material is characteristic of the Madera series. In places it is mottled gray and brown, and in others it consists of grayish indurated beds of considerable thickness. The undifferentiated hardpan-free material is in this area recognized as Gridley material. The hardpan in nearly all cases interferes with root development.

Several of those bodies north of Biggs are more shallow than the typical soil, and in some instances represent transition zones between the soils of the Madera and Gridley series and the adjoining Corning soils.

The clay loams do not vary from the silty clay members in any important detail other than texture.

Very small bodies of rather silty clay material are included which resemble the Madera and the Gridley clay adobe types in all essential features except structure.

*Location.*—The Madera and Gridley clay loams (undifferentiated) occur in numerous scattered, irregular areas, covering in the aggregate a considerable acreage. The most extensive single bodies occur northeast of Butte City, west of Gridley, and north of Chandler, while other areas are encountered northwest and southwest of Yuba City.

*Topography and drainage.*—A large part of the area covered by this group lies somewhat lower than the bordering soils of the same series, and is saturated throughout the rainy season. In these localities drainage is necessary before the land can be productive. The area near Butte City occurs as a remnant slightly higher than the types of the Columbia series bordering it on the west, yet dissected along certain lines by overflow channels which cause destructive erosion. During high stages of the streams surplus waters escaping from the Sacramento River bottoms flow across some areas of this group toward the lower lying Butte Sink region. Little deposition accompanies such overflows, the channels eroding deeply and the tendency being toward the removal of the soil material. A hog-wallow surface characterizes the large body north of Biggs, except where recent stream action modifies the surface and produces a sandy, leachy phase. No alkali is encountered.

*Utilization.*—Some of the soils of this group were originally covered with oak groves. Most of the timber has been removed and the land devoted to the growing of grain. At present the larger part of this

group is used for grain production or pasture, the intensive development on the Madera and Gridley loams (undifferentiated) not yet being extended to this group. The soils are often situated at greater distances from shipping points, and for this reason and the difficulty of cultivation they are less attractive to farmers for the production of intensive crops. They are on the whole less well adapted to these purposes because of their physical characteristics, yet are capable of much greater agricultural development than they at present show. With drainage of the lower areas and careful handling, fair crops of alfalfa and grapes can be grown. Sorghum and other forage crops are also possible. Fruits and crops which thrive on heavy-textured types do best on these soils.

MADERA AND GRIDLEY CLAY ADOBES (UNDIFFERENTIATED).

*Description.*—The Madera and Gridley clay adobes (undifferentiated) consist of reddish-brown or brown clays which are very sticky when wet and have a pronounced adobe structure upon drying. In rare instances there is a thin layer of silty material on the surface. This layer occurs only in the lowest areas where the soils are influenced by local deposition. The soils placed in this group usually have a well-granulated structure and are comparatively easy to till. In that part of the group associated with the Madera series more or less firmly indurated hardpans and semicemented layers of gray or mottled color are encountered at depths ranging from 24 to 36 inches. This hardpan is usually high in calcium carbonate and interferes with root development and the percolation of water. It is often quite easily penetrated by the soil auger, yet when exposed to the air in cuts it becomes much harder and brittle. The cemented material in places extends downward for several inches, grading into compact subsoils. In other places it extends to depths of 6 feet or more.

*Location.*—The Madera and Gridley clay adobes (undifferentiated) are most extensively developed as a large body east of Butte City. They also occur in two or three areas in the vicinity of Biggs.

*Topography and drainage.*—The large area of these soils east of Butte City has a rather uniform surface, its upper part being marked only by remnants of abandoned stream channels and small knobs of the Corning soils. Its southern and lower extensions are rather deeply dissected by a system of closely set erosion channels which carry surplus flood waters. The main channel of Butte Creek crosses the types. Through processes of erosion and deposition these soils are being replaced by other material, such as the Stockton clay adobe or the alluvial and basin soils of the Sacramento bottoms. The subsoil with its hardpan features is extensively exposed along these waterways, and the intervening low ridges often have a silt covering over the characteristic adobe soil which occurs at shallow

depths. The large body of these soils in the vicinity of Biggs has somewhat indefinite boundaries, since it passes by gradations in color into the Stockton clay adobe on the west and by irregular variations in other features into the soils bordering it on the east. Some of the small bodies of the Stockton clay adobe within areas of the Madera and Gridley series east of the Marysville Buttes are partly brown in color rather than black, and such brown or reddish-brown phases of clay adobe bearing calcium carbonate hardpans are properly classed as the Gridley clay adobe.

*Utilization.*—The greater part of this group is dry-farmed to grain, those areas most severely dissected or overflowed being used for pasture. Very good yields are secured. A few small fields of rice are grown in the Biggs region where the surface is flat. This crop can be profitably grown over all these soils where topography permits.

The soil group, where irrigated, is capable of producing such crops as beans, sorghum, alfalfa, certain vegetables, and a few of the hardier fruits.

#### YOLO SERIES.

The soils of the Yolo series are light-brown to dark grayish brown as contrasted with the more reddish or yellowish brown Willows series. The subsoils are lighter colored, varying from yellowish brown or light brown to brown. They are alluvial in origin and occupy stream bottoms, alluvial fans or aggregates of built up stream-laid ridges in association with other soils formed in a somewhat similar manner. The material is derived from a rather wide range of sedimentary and metamorphic rocks, the latter usually predominating. The surface is level or uneven and good drainage prevails as contrasted with the associated Capay series. Groves or scattered specimens of valley oak occupy the main bodies with a greater variety of trees along the streams. The soils vary in texture from fine sandy loam to clays, but are all rather deep, friable, and free from alkali.

#### YOLO FINE SANDY LOAM.

*Description.*—The Yolo fine sandy loam consists of 15 inches or more of fine sandy loam of light-brown or grayish-brown color. The subsoil is subject to considerable variation, but is often a brown fine sand or fine sandy loam which frequently contains strata of loam or silt loam. Coarse sandy streaks and thin beds of silt likewise occur. East of Davisville it is underlain at shallow depths by a clayey material similar to that about the margin of the Yolo Basin. The sandy loam surface is sometimes covered to a depth of a few inches by wind-blown sand, and near the creeks the upper 6 or 8 inches of soil may be similar to the Yolo loams in texture, the difference in

type being due to the lighter texture of the underlying soil. Along Putah Creek, the soil is often of great depth and uniform texture, but portions of it approach a silt loam throughout the entire soil section.

The following table gives the average results of mechanical analyses of samples of the soil and subsoil of this type:

*Mechanical analyses of Yolo fine sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
21170, 21172.....	Soil.....	0.2	1.2	2.2	25.2	36.3	23.3	11.6
21171, 21173.....	Subsoil.....	.0	1.1	2.4	21.4	33.3	28.8	12.9

*Location, topography, and drainage.*—In common with other members of the series, this soil is confined to the western part of the area surveyed. It is developed in numerous small bodies along Cache and Putah Creeks or their distributaries. The surface is generally slightly sloping or undulating, which combined with the open texture of the soil favors drainage. On the other hand, the soil has strong capillary power, and favorable moisture conditions are maintained during the growing season.

*Native vegetation.*—Most of the type is cleared and under cultivation, except along the streams, where the soil is overgrown with willow, cottonwood, and alder.

*Utilization.*—The type is largely dry-farmed to grain with high average yields. Alfalfa, peaches, apricots, almonds, and grapes are grown in different parts of its area. Near Davisville and Woodland sugar beets are grown. It is believed that prunes yield heavier crops on this type than on the adjacent heavier soils, the principal orchards being located west of Woodland and at Yolo along the south side of Cache Creek. Alfalfa produces from 5 to 7 tons per acre with irrigation. Small tracts which are rented to Italian gardeners and kept in cultivation the year round produce a variety of truck crops.

The type is well adapted to deciduous fruits, alfalfa, sugar beets, truck, and a wide variety of general farm crops. The type is free from alkali and is capable of producing many crops without irrigation. The yields are greatly increased, however, when water is applied. It is well located for marketing products and is already in a comparatively high state of cultivation.

#### YOLO LOAMS.

*Description.*—The Yolo loams as mapped in this area comprise the Yolo loam and Yolo silt loam.

The Yolo loam consists of a light-brown or brown loam of medium to heavy texture. Gravel is usually absent and the soil as a rule is

friable and easily tilled. Considerable variation in the subsoil is noted, but below a depth of 24 inches it often grades into a silty loam or sandy loam of a buff or brownish-yellow color. Clay loam or clay at times constitutes the deeper subsoil and gravelly beds may occur at a depth of 4 to 6 feet along the site of old stream channels. Altogether the type shows decided variations in the texture of both soil and subsoil, as indicated by borings taken at close range.

The Yolo silt loam is friable in texture. Typically it consists of 36 inches of light-brown or dark grayish brown silt loam of heavy texture. The soil frequently grades into yellowish-brown substrata of silty clay, clay loam, or similar materials.

Extreme ranges from layers of sandy loam or sand to clayey beds are encountered in the subsoil of a single boring, but on the whole the group is friable when cultivated and retentive of moisture. On the other hand the soils are sufficiently open and porous to drain quickly.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Yolo loams:

*Mechanical analyses of Yolo loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Yolo loam:								
21176, 21178.....	Soil.....	0.1	0.4	0.9	9.5	27.3	43.3	18.2
21177, 21179.....	Subsoil....	.0	.4	1.4	14.3	16.5	49.3	18.1
Yolo silt loam:								
20274.....	Soil.....	.0	.1	.1	1.2	5.0	69.1	24.4
20275.....	Subsoil....	.0	.0	.0	1.7	9.1	61.3	27.9

*Location.*—The Yolo loams occur along Cache and Putah Creeks and within zones of deposition by their distributaries. Some of the largest bodies occur in the vicinity of Woodland, Winters, and Yolo, and to less extent about Davisville. Some long narrow bodies are mapped in the vicinity of Dixon and a rather large area at Vacaville. Several small bodies are found in the southwest part of the area, one of which lies in the extreme corner.

*Topography and drainage.*—The Yolo loams usually occur along stream-built ridges or the slightly higher alluvial slopes leading to them or as narrow bodies of alluvial material with surfaces which are flat or ridged in a low undulating manner. Where the group occupies positions on the valley plain the soils are usually somewhat elevated above surrounding soil areas. The body at Vacaville represents alluvial fan material of good slope. Drainage is usually excellent. Alkali is usually absent, but is found in sufficient amounts to affect the growing of crops in a few small areas. One or two such areas lie south of Woodland.

*Utilization.*—Owing to their excellent drainage and comparatively open texture, with good water-holding capacity, the Yolo loams are well adapted to peaches, almonds, prunes, grapes, alfalfa, sugar beets, garden vegetables, and other cultivated crops. Grain is still extensively grown with good yields. At Vacaville the group produces heavy yields of a variety of fruits.

It is generally realized that irrigation is the best method of utilizing these soils and the practice is constantly increasing. Probably less than one-half the total area is now irrigated. This group is one of the best general purpose soils in the region and is capable of a high degree of intensive development.

#### YOLO CLAY LOAM AND CLAYS.

*Description.*—Included in this group are the clay loam, clay and silty clay soils of the Yolo series as recognized in this survey. The types are essentially the same as mapped in the survey of the Woodland area, together with some additional bodies to the southward.

The Yolo clay loam consists of a light-brown or grayish-brown clay loam of somewhat variable character. When dry the soil may appear very grayish but when wet the brownish tints are more pronounced. At a depth of 2 or 3 feet the color becomes light yellowish brown, or even brownish yellow, the texture of the subsoil being a heavy clay loam or clay. In its occurrence near stream channels the subsoil may be a light silt loam with occasional streaks of sand. In surface appearance and ease of cultivation it closely resembles the Yolo silty clay.

The Yolo clay is a light-brown or dark grayish brown clay, sometimes extending to 6 feet or more in depth. Below 3 feet the subsoil usually assumes a lighter color and a more silty texture. In general its admirable structure makes it appear lighter textured than many other clays of the area. It is more difficult to till than the Yolo clay loam or silty clay, but with good management remains in a friable condition.

The Yolo silty clay consists of 3 to 6 feet of brown to dark grayish brown silty clay, generally underlain at considerable depth by a light brown or brownish yellow clay loam or clay. The texture varies within narrow limits, being often sufficient to affect the ease of handling. The soil is usually smooth to the feel and sufficiently granulated for easy tillage if well handled.

As indicated, the structure of the entire group may be slightly compact, but the soils are generally inclined to be rather friable and easily tilled, as contrasted with the clayey types of the Capay series. Some local bodies in a naturally puddled condition are much harder to till than the typical soil. Although freedom from coarse material characterizes the group, the structure is such as to make the soils more ab-



sorptive and retentive of moisture than is usual with soils having such a high clay content. The members of the group do not vary widely in their main characteristics.

The humus content is sufficient for ordinary purposes. As already noted, the soils have quite a dark grayish cast when dry, becoming more brownish when wet. The clay and clay loam members of the group predominate.

The following table gives the results of mechanical analyses of soils and subsoils of the members of this group:

*Mechanical analyses of Yolo clay loam and clays.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Yolo clay loam:								
21180.....	Soil.....	0.0	1.9	3.9	16.6	16.6	42.1	19.0
Yolo silty clay:								
20276.....	Soil.....	do.	.1	.1	3.2	5.0	58.3	33.5
20277.....	Subsoil.....	.0	.0	.3	5.0	12.3	53.8	28.5
Yolo clay:								
20133, 21182..	Soil.....	.0	.1	.1	.9	7.6	50.9	40.4
20134, 21183..	Subsoil.....	.0	.1	.1	.7	10.9	55.4	32.6

*Location.*—This group occupies important areas on the west side of the valley in the vicinity of Yolo, Woodland, and Davisville, covering much of these regions and extending in irregular areas along Cache and Putah Creeks to where they emerge from the low rolling hills bordering the valley slopes. Some of the areas are very extensive and together with smaller ones in association with the Capay series cover much of the valley plain over an extensive belt. The clay loam member occurs largely north of Cache Creek, with smaller bodies between this and Putah Creek. The Yolo clay occupies numerous areas north of Putah Creek and along Willow Slough and Cache and Putah Creeks. The silty clay member occurs principally along Cache Creek and near Woodland, with smaller bodies near Winters. The group south of Putah Creek comprises these types in mixed occurrence. These soils gradually merge with one another and other bordering soils, sharp boundaries being rare.

*Topography and drainage.*—The surface is subject to but slight variations, being for the most part smooth or very slightly undulating or sloping and marked here and there by creek channels or their distributaries. The clay type is often confined to elevated ridges along minor stream channels where it may be associated with the Yolo loams. When associated with soils of lighter texture the group generally occupies a lower topographic position, such as local flats slightly removed from the streams. At such points drainage could be profitably supplied, but, generally speaking, the group is

amply drained for all ordinary purposes. About the margins of the Yolo Basin a limited area is overflowed by backwater and at times of excessive precipitation nearly all of the soils, except those on the crests of the ridges, may be flooded for short periods by intermittent streams. Small quantities of alkali occur in the depressed areas.

*Native vegetation.*—In its native state this group of soils was generally covered with oaks, while the heavy textured types of the adjacent Capay series typically were not. Nearly all the group has been cleared.

*Utilization.*—These soils are all used for agriculture. In point of acreage grain predominates, but eventually this will give way to intensive crops. The soils produce good yields of wheat, barley, fruit, and alfalfa, and considerable development has already taken place both with and without irrigation. The clay loam member is an important fruit and alfalfa soil. The readiness with which the soils of this group conserve moisture makes them especially adapted to dry farming, but it can be safely said that all crop yields, even upon the most favorable phases, would be increased by irrigation. Frost conditions vary over the group, the flatter portions being more subject to early frosts. Many of the fruits suited to sandy soils do not give maximum yields on this group and the same may be said of those requiring only a low organic matter content, such as olives and certain varieties of almonds. The crops best adapted to these soils include alfalfa, sugar beets, a long list of garden vegetables, and the already established varieties of fruit. Many varieties of grapes, including both raisin and wine varieties, give good yields. In addition to the crops mentioned the soils are well adapted to beans, sorghum, Egyptian corn, and various other general farm crops.

#### HANFORD SERIES.

The soils of the Hanford series are generally light grayish brown or buff to light-brown in color. They are micaceous, smooth to the touch, friable, and porous. Typically they are 6 feet or more in depth, but are often underlain by various beds of alluvial deposits. These soils are usually recent alluvial in character, being deposited both as alluvial fans and as stream-bottom or terrace material. In this area a considerable part of the series occurs as elevated terraces of older deposition. These are derived from a wide variety of rocks, but granitic material often seems to predominate.

#### HANFORD FINE SANDY LOAM.

*Description.*—The Hanford fine sandy loam consists of 24 to 72 inches of light-brown, buff, or grayish-brown, extremely friable fine sandy loam bearing a relatively high content of mica. The bodies of most recent deposition are usually lightest in color. In local

bodies the texture approaches a sandy loam, fine sand, or even a loam, but the total extent of such departures from the typical soil is not great. The most recently deposited bodies have a very smooth texture, by reason of their high mica content. The soil is very permeable and retains moisture well. It is usually quite uniform in texture to a depth of 72 inches. Those portions of the type of most recent deposition and lightest texture usually carry more mica, and in a coarser form, than the older bodies. In places, along the margins of the large body of the type about Lodi the soil is underlain by material of the Madera or San Joaquin series at a depth of less than 6 feet, and while it may here possess all the variations of color and hardpan afforded by those series the total acreage of such areas is not extensive. Gravelly substrata nearly always underlie the type below 6 feet, and in spots are found at any depth from a few inches downward. In places where erosion has been most active gravelly streaks may appear.

*Location.*—This type is most highly developed as the broad alluvial fan and present bottoms of the Mokelumne River in the southeastern part of the area. Very important bodies likewise occur along the American and Cosumnes Rivers.

*Topography and drainage.*—The Hanford fine sandy loam occupies in this area two rather distinct topographic positions. The first of these comprises alluvial bottoms such as those along the American, Mokelumne, and Cosumnes Rivers, where the type is but slightly elevated above the parent streams. It is in these instances a recent alluvial product, marked by channels or remnants of channels and overflow ways, forming a distinct bottom with small differences in elevation, yet approximating in slope the streams along which it lies. The outer margin of the bottoms may be separated from the bordering upland soils by distinct terraces, as is the case along the Cosumnes River for many miles and along the Mokelumne River. In the latter instance, however, the soils above the terrace are still considered as the Hanford fine sandy loam of earlier deposition. It appears that the latter stream or its equivalent has in times past built up a huge alluvial fan, through which it has at this time lowered its bed with the accompanying present alluvial bottom. The second phase of Hanford fine sandy loam occupies the remains of this delta as a sloping fan, converging upstream to that point where the river emerges from its narrow confines within a rolling country. It is interesting to note that the terrace bounding the alluvial phase becomes less pronounced as the valley trough is approached, until with their obliteration the river bottom and delta phases are merged. The latter phase comprises most of that important body in the Lodi section. Its surface is smoothly sloping and marked with occasional low ridges of old distribution, roughly radiating from a general locality on the Mokelumne River a short distance below Lockeford. Surface

and subdrainage are good. Some of the river-bottom areas are overflowed and may have a rather high water table, but seldom contain alkali. The type is all capable of being highly developed by irrigation.

*Utilization.*—The type was originally covered with a heavy tree growth, willow, cottonwood, sycamore, and many other trees of this class occupying the river bottoms, while oak predominated on the delta land. Little of these growths now remains except near streams.

The Hanford fine sandy loam is one of the most highly prized types in the area. Some of the best farms in the valley are located upon it and a great variety of fruits, including peaches, pears, prunes, almonds, apricots, many varieties of grapes, berries, figs, olives, and bush and vine fruits are grown. Flame Tokay grapes reach a high degree of perfection and their production comprises an important industry. A wide range of general farm crops, including grain, alfalfa, corn, potatoes, and intensive truck crops, are profitably produced. Some of the most productive hop yards in the State are located along the Cosumnes River. The delta and river-bottom lands are adapted to about the same range of crops, although frost conditions are a little more favorable on the higher lands. The type is much sought for intensive development and the ordinary holdings are smaller than in the case of other types.

#### SOLANO SERIES.

These soils are prevailing yellow when dry, but often assume a brownish or light-brown color when wet. The subsoils are light brownish yellow, usually compact, and heavier textured than the surface soils, but become more friable and lighter textured at a depth of about 3 or 4 feet. The deeper subsoil is of distinctly yellow color. The surface is sloping to flat, the flat topography often being associated with poor drainage. These soils are alluvial in origin, the heavier members having been deposited under poor drainage conditions. The rocks and soils giving rise to the Altamont series have largely contributed material toward the formation of this series.

#### SOLANO LOAM AND CLAY LOAM.

*Description.*—The Solano loam consists of a rather sticky loam of compact structure and low organic matter content. When dry the soil is grayish yellow or brownish yellow in color, and when wet it is light brown or grayish brown. The subsoil occurs at a depth of 24 to 36 inches and consists of a distinctly yellowish clay loam or clay which is locally very compact. In many instances the heavy subsoil becomes lighter with depth until a rather friable loam is reached at about 60 inches.

The Solano clay loam consists of 20 to 30 inches or more of brownish-yellow, sticky clay loam of compact structure. It is not easily tilled. Spots having a dark-gray color and a pronounced adobe structure occur in poorly drained local flats.

*Location.*—The Solano loam and clay loam are extensively developed in the southern part of the area lying east and northeast of Suisun. Small bodies also occur about the lower margin of the Montezuma clay adobe. It is possible that portions of the region west of Elmira and Dixon should have been classed with this group.

*Topography and drainage.*—This group occupies the valley slope, merging on the west with the higher lying Altamont soils occupying the lower foothills. From this series it extends with constantly decreasing slope to the southeast, where it finally merges with the lower lying and flatter Solano clays and associated types. Its entire extent is diversified by the occurrence of knobs, knolls, and ridges occupied by the Altamont series as residual types from outlying remnants of the sedimentary rocks composing the lower foothills. A rather marked tendency toward a "hog wallow" surface is apparent over much of the group, being in parts of the clay loam very pronounced. Surface drainage is only fair and in nearly all instances subdrainage is very poor, causing the subsoil to have a mottled appearance. Portions of these soils contain injurious quantities of alkali, for which reason some areas have been devoted to pasture for many years past. The presence of the alkali in such places is evidenced by surface accumulations, barren spots, and the presence of salt grass and other forms of alkali-resistant vegetation. In places the upper few inches of soil may be practically free from alkali, while the subsoil bears high percentages. In some cases the alkali has been deposited by evaporation of soil moisture supplied by a high water table. In some of the rather sloping areas, however, the mineral salts have accumulated through the evaporation of seepage or percolating waters seeking lower levels.

*Utilization.*—Practically all of the cultivated portions of these soils are devoted to the production of grain under dry-farming methods. Much of them is given over to pasture. While the yields have been fair, the farmed area seems to have decreased. Much of the group does not appear to be highly productive under present agricultural practice, but some portions of it are adapted to intensive cultivation at this time.

#### SOLANO CLAYS.

*Description.*—The Solano clays represent a group of soils rather variable in their principal characteristics, yet consisting for the most part of the clay or silty clay of the Solano series. The average composition is that of a slightly brownish-yellow clay, free from grit or

gravel, and of compact structure. At a depth of 2 to 3 feet the soil becomes a little lighter in texture, with a more decided yellowish color, the last few inches of the 6-foot soil profile being often a loam in texture. The subsoil and substratum are very often mottled. Some of the most poorly drained bodies mapped are grayish or dark gray in color and of adobelike structure.

The silty clay is usually a little better drained than the clay and may include small patches of the lighter types of the Solano series inclosed as slightly elevated hummocks or low ridges not of sufficient size to map.

Most of the soil group appears brown under wet field conditions, but when fairly dry exhibits the rather typical yellowish cast of the series. The group as a whole is of intractable structure and difficult to handle.

*Location.*—A single body of this group of soils is mapped southeast of Elmira as a rather broad area representing the lower extension of the valley slope.

*Topography and drainage.*—The soils of this group occupy a flat, poorly drained region containing numerous intermittent lakes. They are rather poorly differentiated on the western margin from the lighter textured, higher lying types of the same series, and are also somewhat arbitrarily separated from the adjacent types on the east. The surface is not subject to much diversification other than that afforded by hog wallows and drainage ways. Occasional barren alkali spots, together with the hog wallows, intermittent lake beds, and small stream courses all combine to give the surface a rather spotted or uneven appearance.

*Utilization.*—The soils of this group are entirely treeless and shrubless and have only a sparse growth of grasses among which salt grass (*Distichlis spicata*) is often prominent. Much of the area covered by the group is untilled, being used only for pasture. Portions of these soils which are free from alkali and have better drainage than usual may be utilized, when irrigated, for general farm crops, including alfalfa, grain, sorghum, and forage crops.

#### TEHAMA SERIES.

The soils of the Tehama series vary somewhat in color but pale yellow predominates with brownish, reddish or grayish phases. The subsoils are usually light brown, brownish yellow or yellowish brown. Both soil and subsoil often appear light brown when wet. These soils are often compact and rather puddled, but are usually free from hardpan or cemented layers. Quartz gravel is abundant in places, giving rise to the gravelly members. The surface is level, slightly uneven or sloping and sometimes eroded. These soils are predominantly of alluvial or alluvial-fan character, but may include minor

areas of stream bottom or stream terrace. Some of the bodies are now elevated above existing waterways. The series seems to be derived from the material giving rise to the Kimball, Corning, and Redding series of soils and from the massive beds of yellow silty material by which they are underlain in certain parts of the west side plains.

#### TEHAMA LOAMS.

*Description.*—The Tehama loams include the fine sandy loam, silt loam, and loam of the Tehama series. The silt loam member is usually free from gravel, but the loam and fine sandy loam often bear small quantities. Aside from this characteristic, the soils are not essentially different, except in texture. Over the larger part of its extent the group consists of light brownish yellow, light reddish yellow, or grayish yellow soils of rather compact structure ranging from a slightly gravelly loam to a compact silt loam free from gravel. This material extends to a depth of 12 to 30 inches, where it grades into subsoils ranging in texture from clay loam to clay and brown or light brown in color. When dry the color of both soil and subsoil appears distinctly pale yellow, but when wet it becomes light brown. Where gravel is present it consists almost entirely of fine, well-rounded and sub-angular quartz fragments, apparently identical in character with that accompanying the soils of the Redding, Kimball, and Corning series. Included within this group of soils as mapped is a broad area in the Corning locality and smaller bodies throughout that general region having a more grayish color and a more friable structure than common. A great deal of the lower extensions of the area are also of this character. A part of these soils north of Stony Creek includes patches having a distinctly reddish color which are intermediate in character between the Kimball loam and the Tehama loams. The soils in question are everywhere marked by gritty or gravelly streaks along present washes or indistinct, long-abandoned drainage ways. These localities are usually elevated by the deposition of material and may be shown only by meandering streaks of gravelly soils. These gravelly streaks or ridges are often accompanied by subsoils of a rather more gravelly and porous nature than common. The heavy-textured subsoils are often underlain below 6 feet by beds of compact silt, sand, and gravel, and occasionally approach within 2 or 3 feet of the surface. The Tehama loams are not usually underlain by hardpan, but in a few instances hardpan and cemented layers common to near-by types may extend under them within 6 feet of the surface. Included within this group are some areas of fine sandy texture lying southeast of Orland, which are a little less yellowish and more grayish in color and more porous in structure than typical with lighter and more friable subsoils. Wind action has influenced the development of this variation to a small extent.

The Tehama loams, as indicated, include gradations of material in both soil and subsoil, with irregular transitions the rule. What is said of variations within the group is likewise true of the marginal areas separating it from other series. In the vicinity of soils of the Willows series the color approaches the brown of those soils and an arbitrary boundary is necessary.

The following table gives the results of mechanical analyses of samples of the soils and subsoils of the Tehama loams:

*Mechanical analyses of Tehama loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Tehama silt loam:								
24168, 24170.....	Soil.....	0.5	1.2	1.7	8.2	17.7	57.1	13.4
24169, 24171.....	Subsoil .	.0	.5	.8	6.3	23.1	47.6	21.4
Tehama loam:								
14715, 14717, 16792.	Soil.....	2.9	8.5	5.7	12.8	11.6	45.6	12.4
14716, 16793.....	Subsoil .	.6	2.0	3.5	7.3	11.4	42.8	31.7

*Location.*—The Tehama loams cover broad areas in several parts of the west-side valley slopes. They comprise the soil covering most of the smoother portions of the valley plains from Willows to Orland and from the former town to the head of the valley the group is extensively developed. One of the most typical bodies of the silt loam, a rather gravel-free member, occurs about Rawson south of Red Bluff. Another important development of the group occurs in the vicinity of Arbuckle. Smaller isolated bodies frequently occur in association with the Corning gravelly loams.

This group of soils includes the type mapped as Orland fine sandy loam in the Colusa area which is now recognized as a member of the Tehama series. It also includes in general the San Joaquin loam of the Colusa area and in part several types previously recognized in the Woodland survey as members of the Arbuckle series. The Maywood loam of the Red Bluff area is also in this survey considered as a variation of the Tehama loams, from which it does not greatly differ.

*Topography and drainage.*—Most of the group in the northern part of the valley uniformly occupies elevations slightly below the Redding, Kimball, and Corning series, being in most cases separated from them by pronounced slopes or terraces of several feet. From the lower lying soils of the Elder and Sacramento series it is again separated by terraces, often pronounced along the alluvial flood plains of the Sacramento River. It here occupies regions of intermediate elevation, with almost uniform plains of gentle slope sometimes marked by minor drainage ways and slightly dissected at terrace lines. Over



much of the surface of this phase there are small minor depressions having no outlet, oftentimes giving the appearance of a "hog-wallow" topography. In this northern phase the main drainage ways usually occupy lower miniature valleys, leaving most of the group elevated and subject to little modification except erosion. Southward the soils of the group consist more often of alluvial fan material than elevated terraces.

The Tehama loams are usually well drained. Some of the flattest elevated terraces in the northern part of the survey accumulate much surface water in the small depressions before mentioned, and the impervious nature of the subsoil promotes puddling during especially wet periods. It is at times a difficult soil to handle in that locality under an extensive system of agriculture, but is easily improved by digging small ditches to remove the excess surface water. Very little of the group is overflowed, but some of the larger streams in its southern area deliver much water across the types through gravelly washes. Drainage is deficient only in the flatter "hog-wallow" areas and the lower extensions of the group where the slope is much less than usual.

*Native vegetation.*—The greater part of the Tehama loams was originally treeless and shrubless, but supported a growth of native grasses. Exception is made of a part of the region southwest of Arbuckle, however, where a brushy tree growth accompanied by a few conifers occupies the upper slope of the group, and of wooded areas adjacent to the Sacramento River.

*Utilization.*—When grain production was at its height this group of soils was nearly all utilized and gave profitable returns, but its use has decreased because of lessened yields. Summer fallowing is the rule, portions of the type being cropped only every third or fourth year. The flattest puddled portions seem to yield best in years of minimum rainfall.

The greater part of the group is not well adapted to the production of crops other than grain under dry-farming methods. In some cases, however, almonds (see Pl. III, fig. 1), olives, grapes, and figs have been profitably grown by good cultivation without irrigation. Quite a wide range of crops can be grown under irrigation.

#### TEHAMA GRAVELLY LOAMS.

*Description.*—This group includes the gravelly loam and gravelly sandy loam of the Tehama series.

The Tehama gravelly loam consists of a medium-textured loam carrying varying quantities of waterworn gravel, coarse sand, and fine angular rock fragments and extends to a depth of 18 to 72 inches. It varies in color from brownish yellow or yellowish brown to reddish gray or brownish gray. The coarse material is usually quartzose.

Where the soil is less than 6 feet deep, it is underlain by a compact light-brown or yellowish-brown loam, clay loam, or clay.

The Tehama gravelly sandy loam consists of a yellowish-brown or grayish-brown gravelly sandy loam. It is often 6 feet or more deep, but may be underlain below 18 inches by gravelly beds of coarse, incoherent structure or by a clay loam resembling that of the gravelly loam member. The coarse material varies in quantity, but, as in the gravelly loam member, corresponds in character to that so prevalent in the Corning and Redding gravelly loams.

The Tehama gravelly loams are rather friable soils, but at times show the same tendency to clod, bake, and puddle that is manifested by the other types of the same and allied series. The organic-matter content is low.

The types mapped in the Colusa and Woodland areas as Sacramento gravelly sandy loam, Sacramento loam, and Arbuckle gravelly sandy loam are in part included in this group.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Tehama gravelly loam:

*Mechanical analyses of Tehama gravelly loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24174, 24176.....	Soil.....	5.2	5.0	3.3	8.9	26.6	38.3	12.5
24175.....	Subsoil. ....	1.5	2.1	1.8	6.7	28.0	32.1	27.3

*Location.*—This soil group occurs as numerous small bodies of elongated outline bordering present intermittent streams, or as terraces or benches along former stream courses somewhat above existing drainage ways. It may occupy positions as stream-built ridges down the valley slopes or as flattened bodies within small valleys, depending largely on the character of the individual stream and the regional slopes at its occurrence. Most of the small bodies occurring northward from Orland occupy stream-bottom positions. The most notable instance of an elevated ridge condition over the valley slope is afforded by a striking gravelly strip which persists from the vicinity of Orland southward almost to Willows. The soils are usually well drained, but the lowest portions are subject to overflow.

*Utilization.*—Considerable areas of these soils are farmed to grain, but this constitutes practically their only agricultural use. With good care a few dry-farmed orchards of almonds and peaches have been brought to bearing, but it requires irrigation to insure intensive development. The soils are capable of supporting a wide range of crops with irrigation and there are sufficient large well-located areas to make them of great agricultural value.

Peaches, berries, almonds, apricots, and other crops, including melons and alfalfa, thrive on these soils, but they need more frequent and liberal applications of water than on the Tehama loams. Intensive farming on a small scale is generally impossible without irrigation. Underground water for irrigation can be secured in varying quantities by pumping, but it has not yet been demonstrated that the full needs of an intensive system of agriculture can be supplied in this manner. Gravity systems of large scope will probably be installed before the greater part of this type is developed in any other way.

#### TEHAMA CLAY LOAMS AND CLAY.

*Description.*—The Tehama clay loams and clay include the clay and silty clay loam of the Tehama series.

The Tehama clay constitutes the most refractory member of the series and typically consists of a compact clay ranging in color from yellowish brown to light grayish brown. When wet it is very sticky and upon drying soon acquires a hard, baked condition, with cracks and checks. It is difficult to till. In a few instances this mantle of soil is underlain at about 36 inches by a layer of rather impenetrable character defined as a remnant of the Redding or Corning series. Usually, however, the subsoil below about 36 inches consists of a heavy, compact, light-brown, yellowish-brown, or reddish-brown clay loam or clay of dense, adobelike structure. The type throughout is free from gravel.

The Tehama silty clay loam consists of a sticky clay loam or silty clay loam of compact structure, averaging about 36 inches in depth. In places the soil may be gray or ashen gray in color, but typically it is about the same color as the Tehama clay. It is somewhat more easily tilled than the clay, but is inclined to puddle. Portions of the group northeast of Willows have a dark grayish-brown color, sometimes approaching the dark-drab phase of the Sacramento series. In places the soils merge so imperceptibly with adjacent soils that the boundaries are arbitrarily drawn. Undifferentiated bodies of associated types are included within the areas of these soils.

Some of the heavier types of soils mapped in the survey of the Colusa area under the Willows series are in part included in this group.

The following table gives the average results of mechanical analyses of samples of the soil of the Tehama clay:

*Mechanical analyses of Tehama clay.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24172, 24173.....	Soil.....	2.1	2.0	1.8	4.9	18.5	34.9	35.5

*Location.*—This group of soils occurs in numerous elongated and slightly depressed bodies. It is most extensively developed northeast of Willows, but there are scattered areas from that point northward for many miles. It sometimes occupies small depressed areas bordering the Redding series. An area of considerable size occurs in the Hungry Hollow region north of Esparto which is somewhat better drained and more friable than usual.

*Utilization.*—At one time considerable grain was grown on these heavy types of the Tehama series, but owing to decreased yields the acreage devoted to this purpose has been considerably reduced.

Good crops of grain are yet produced during favorable seasons on the better portions of the types, but much of the land is used for pasture. The indications are that when well-drained alfalfa, fruits, and some of the general farm crops can be profitably grown on these soils.

#### COLUMBIA SERIES.

The soils of the Columbia series range in color from light brownish gray to light grayish brown or buff and are usually free from gravel. The lighter members are usually micaceous, but less so than the Hanford series. The subsoils are often stratified and variable in texture, but are similar to the surface soils in other features. In places both soil and subsoil show more pronounced tints of yellow or brown than usually occur. The soils are 6 feet or more deep, but often have gravelly substrata below that depth. They are alluvial in origin, being composed of material derived from basic and acid igneous, metamorphic, and sedimentary rocks, much of which has been transported great distances. As encountered in this survey the series occupies present or recent flood plains. The surface varies from level to irregular, and sloughs and lagoons are of frequent occurrence. The soils are often subject to overflow, and the lower depressions are poorly drained. In this area the Columbia series includes the lighter textured and lighter colored types formerly mapped under the Sacramento series in various detailed surveys in this valley. As previously recognized, the Sacramento series embraced material varying widely in color, while now only the darker colored members of the series are recognized as Sacramento material. These darker colored soils are usually subject to overflow where unprotected and have been accumulated or modified under overflow basin conditions. As mapped in this survey the Columbia series also includes some of the soils mapped in the earlier survey of the Marysville area as the Bear and the Feather series.

## COLUMBIA FINE SANDY LOAM AND SANDS.

*Description.*—This group includes the fine sandy loam, fine sand, and sand of the Columbia series.

The Columbia fine sandy loam greatly predominates, comprising about 75 per cent of the total area covered by the group. It consists of a light grayish brown, brownish-gray, or buff fine sandy loam of rather smooth texture and porous structure. The type is slightly micaceous. No definite statement can be made regarding the subsoil since it may, from a few inches downward, consist of alternate beds of sediments of all textures found within the series. The fine sandy loam often extends to a depth of 6 feet or more. Negligible quantities of waterworn gravel occur in small areas in the upper part of the valley where the soil has been influenced by swift water action. The organic-matter content of this soil is greater than that of the adjacent soils of the valley plains.

The Columbia fine sand consists of a fine sand, incoherent and porous in structure, and lighter in color than the fine sandy loam. It is micaceous in places, especially along Feather River east of Biggs and Gridley. The subsoil is often similar to that of the fine sandy loam, consisting of irregularly stratified deposits of various textures.

The Columbia sand consists of 2 feet or more of loose, incoherent, light-gray sand. It may continue to a depth of 6 feet or be underlain by varying heavier materials in irregular order.

The following table gives the results of mechanical analyses of samples of the soils of the Columbia fine sandy loam and sands:

*Mechanical analyses of Columbia fine sandy loam and sands.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Columbia fine sandy loam:		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24167.....	Soil.....	0.0	0.5	4.1	35.4	28.0	17.9	13.5
Columbia sand:								
21145.....	Soil.....	.0	3.1	30.5	60.0	2.3	2.2	1.0
Columbia fine sand:								
24165.....	Soil.....	.0	.3	2.2	75.6	15.3	3.1	3.0

*Location.*—Numerous areas of these soils occur along the course of the Sacramento River from the head of the valley to a point a few miles south of Sacramento, where the river gradient ceases to be sufficient for the transportation of this class of material. Large areas also occur along Feather and Yuba Rivers from the points where they emerge from the hills to their confluence at Marysville

and thence to the Sacramento River, and in the American River bottoms. The fine sand and sand members of the group are most extensively developed in the bends of the river courses where flood waters sweep across with greater severity, and in other localities along the river similarly influenced during floods when the surface covering was deposited.

In certain cases the darker colored portions of the series are with some difficulty distinguished from the adjacent soils of the Sacramento series. In the earlier detailed survey of the Marysville area the group includes areas of material formerly mapped under the head of Riverwash.

*Topography and drainage.*—The topography of this group of soils is rather uniform except for the courses of overflow channels and the erosion or pitting of the surface by flood waters, which give it a slightly undulating or ridged appearance. Across some of the broader river bends occupied by the more sandy members of the group deep gravelly streaks of Riverwash occur. In the upper part of the valley this soil group occupies slightly lower elevations than the Columbia silt loams, but farther southward may occupy ridges or areas of slightly higher elevation which slope away from the overflow channel or become lower in elevation as they approach the basins. Practically all of the areas of this group are subject to periodic overflow, except where protected by levees. The greater proportion of these soils, including the areas along the Yuba River and much of those along the Feather River, is not protected. The drainage is usually sufficient and there is little tendency toward the accumulation of alkali.

*Native vegetation.*—These soils were originally covered with a heavy forest growth consisting mainly of sycamore, cottonwood, willow, and oak, with a thick undergrowth. A great deal of the surface has been cleared and cultivated, but much of the lowest and most frequently inundated areas yet remains a thick jungle.

*Utilization.*—A great deal of the Columbia fine sandy loam is unprotected by levees and subject to flooding. There are, however, large areas of this type which are protected from ordinary overflow or removed from vigorous water action, and these are devoted to a wide variety of crops. Irrigation is practiced upon some areas of the fine sandy loam, and its use is increasing, but reliance is often placed upon the large moisture-holding capacity of the soil. This soil is a heavy producer of alfalfa, beans, asparagus, and various truck crops, hops, corn, and potatoes. Many good orchards of Bartlett pears, plums, peaches, prunes, apricots, and other fruits, and English walnuts have been grown without irrigation. The greater part of the type is utilized for the production of dry-farmed grain and good yields are obtained. This is one of the best and most productive soils of the area, and its

intensive development in small farms will depend largely upon engineering difficulties in protecting it from overflow and supplying water for irrigation.

There are some small areas of the Columbia fine sand and sand west of Sacramento and elsewhere, within present reclamation districts, which are being farmed with the other soils of those localities, but the greater part of these soils is not suitable for cultivation, owing to their tendency to droughtiness during dry seasons and their lack of protection from floods; and the great expense that would be involved in their protection and development makes it probable that they will remain in the list of nonagricultural soils for many years.

The soils of this group are adapted to a wide range of crops, and while the fine sand and sand are the least desirable they constitute good agricultural land when protected and irrigated. The lighter portions can be readily utilized for the growing of early truck crops. Maximum yields are obtained by irrigation. Flood relief will be difficult over a great deal of the river bend or worst affected areas, and the present cleared areas can not be much extended without erosion doing great damage.

#### COLUMBIA SILT LOAMS.

*Description.*—The Columbia silt loams as recognized in this area include the silt loam, silty clay loam, and silty clay.

The Columbia silt loam probably comprises 80 or 90 per cent of the group area. It is a light grayish brown, light brownish gray or buff, smooth-textured, friable silt loam, often extending to a depth of 6 feet or more. It has a moderately high content of organic matter and is easily tilled. The lighter textured portions are often slightly micaceous. More pronounced tints of yellow or brown are occasionally encountered, but the departures from typical are infrequent and of small extent. Gravel is rarely present in either soil or subsoil. Where the material is less than 6 feet deep, the subsoils are often stratified and vary in texture, but are similar to the soil in other features. The type has a good water-holding capacity and is adapted to the development of deep-rooted crops. In places, however, there may be encountered seams or bands of material of all textures occurring in the series, sometimes beginning within a few inches of the surface and extending to a depth of 6 feet or more. The silt loam surface soil often grades at depths below 20 to 30 inches into drab or black clayey subsoils, where the group occurs as an overwash or constantly thinning layer about the edges of the Sacramento clay areas. Considerable areas of this character border Yolo and Sutter Basins.

The Columbia silty clay loam consists of a gray, brownish-gray, or buff, smooth-textured silty clay loam, often extending to a depth

of 6 feet or more. Its subsoil is subject to the same variations as that of the silt loam, but is less likely to have the coarser seams or strata within 6 feet. The soil is more compact and less easily tilled than the silt loam, but has a slightly greater organic-matter content.

The Columbia silty clay consists of a silty clay of a slightly darker color than the silt loam and silty clay loam. It grades by slightly darker color transitions into the clayey types of the Sacramento series. Tillage is more difficult than on the other types. The subsoils of this type do not grade into coarse strata with such frequency as the rest of the series and usually exhibit a more uniform profile.

The surface of the soils of the group is often marked by patches of sand distributed along overflow channels or across relatively low bodies swept by flood waters. Below 6 feet coarse gravelly alluvium occurs in many places, but this general tendency decreases along the southern extension of the main valley as the gradient decreases.

The members of this group merge into other types of the same series, from which they are sometimes rather difficult to separate.

The following table gives the results of a mechanical analysis of a sample of soil of the Columbia silt loam:

*Mechanical analysis of Columbia silt loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24160.....	Soil.....	0.0	0.2	0.9	9.2	14.5	58.6	16.5

*Location.*—The Columbia silt loams occupy a great elongated area bordering the Sacramento River upon one or both banks from the head of the valley to below Sacramento. Detached areas occur along Feather and American Rivers and farther southward from the main body. Marginal bodies occur around the elevated edges of some of the islands in the lower river region, being there associated with the Sacramento clay loams or with Muck and Peat. A number of such areas, because of their small size, could not be indicated upon the map. The group in question from Sacramento northward covers the greater part of what is known as the Sacramento bottom soils, river sediments or river soils.

Areas of the silty clay member of the group are found in the upper Colusa and Mormon Basin regions.

*Topography and drainage.*—There are no great differences in elevation within the soils of this group, but the surface is usually marked by overflow sloughs or abandoned channels paralleling the river in a general way. In river bends or where erosion is most severe pits, small depressions, and ridges may appear. In certain localities



sloughs and deep, narrow depressions marking the sites of former stream channels, break the rather uniform surface. In the upper part of the valley the outer margin of this alluvial bottom may be quite definitely bounded by terraces, except where it gives way to permit the entrance of lateral drainage and alluvial strips of foreign origin, which finally lose their identity in the great mass of soil material of the Columbia series. In that region the river occupies the lowest part of the valley trough, but farther south it occupies an elevated ridge flanked by lower lying lands comprising the "basins." Thus, in the upper valley the soils in question slope toward the river or in the direction of its flow, while farther south they slope away from the river to merge on their outer edges with the basin soils. Under natural conditions practically all of this group is subject to periodic overflow. In the northern portion of the valley the overflow depressions before mentioned often carry sufficient water during floods to cover the flatter portions as a sheet or to submerge all but the highest parts. The general slope in the upper valley is usually sufficient to relieve the soil soon after the crest of high water passes, and little effort has been made to construct levees in these parts. Were it not for the levees which have been generally constructed in the remainder of the valley, much of the soils of the group would be overflowed and large areas would remain under water for some time. As it is, there are considerable tracts outside levee systems which it is impossible to till because of adverse flood-water conditions. Under-drainage is usually ample when the soil is protected from flood. The water table generally occurs considerably below 6 feet, averaging deepest in the upper valley, and gradually becoming shallower southward until some of the more southern bodies in the island region have a permanent water table at 3 feet or less. Alkali has accumulated in damaging or dangerous amounts in certain inclosed places of poor drainage where the water table closely approaches the surface. These are indicated in the Colusa, Woodland, and Marysville detailed maps.

*Native vegetation.*—Originally the soils of this group were heavily timbered. In the better drained locations, slightly removed from the stream channels, the valley oak predominated with a vigorous undergrowth. The lower-lying areas, or those most subject to overflow, supported a tangled growth approaching a tropical jungle in density, consisting mostly of cottonwood, sycamore, willow, and wild grape. While a considerable acreage of the group is now cleared for agriculture, there are large sections which have never been cleared, because of flood conditions, and others which have been abandoned after clearing on account of changes in flood conditions. The uncleared area still constitutes a considerable percentage of the soils of the group, and it is impracticable to extend the cleared areas except by building new levees.

*Utilization.*—The agricultural development of these soils has occupied the attention of the farmers of the area since pioneer days. They were cleared slowly and at great expense and were considered among the most important grain soils of the area, producing heavy crops of wheat and barley. The greater part of the cultivated area is still used for dry-farmed grain and there are no such marked decreases in yields as accompanied the continued cropping of the upland soils. The uncultivated portions serve as pasture land or supply firewood and fence posts. It has been found profitable to grow alfalfa upon this group of soils without irrigation. There are also numerous successful orchards which have been developed without irrigation, and other dry-farmed crops, including hops and various truck crops, are produced. All of these dry-farmed crops are produced on the moister areas of the group, which often occupy rather low-lying positions, and therefore it can not be stated in a general way that the entire group is adapted to intensive farming without irrigation. As a matter of fact, much of it is unfit for such use and all of it would be benefited by irrigation. The intensive development of which the soils are capable must be delayed until they are fully protected from flooding, and irrigation will usually be necessary to warrant their use in small tracts. Portions of these soils throughout the valley which have been intensively developed have demonstrated their suitability for a wide range of crops.

Some of the oldest and best yielding orchards of pears, peaches, prunes, and apricots are found upon this group of soils. Sugar beets are grown successfully. Some of the most profitable hop yards in the area are located upon this group, largely upon the friable subsoil phase of the silt loam member. Vineyards of wine grapes at Stanford Ranch at Vina are produced in part upon this latter member. Alfalfa gives maximum yields with irrigation on the lighter portions of the group with friable subsoils. Truck, forage, and hay crops, broom corn, white and brown beans, and nearly every general crop grown in northern California, except the citrus fruits, are profitably produced on these soils, which are among the most valuable in the area.

Differences in texture, drainage, relative permeability of the subsoils, frost conditions, and other features make the group more suitable in certain places for some crops than others.

#### SACRAMENTO SERIES.

The soils of the Sacramento series are dark gray, drab, or black in color and are usually characterized by a high humus content. They are often 6 feet in depth, but when less are generally underlain by lighter colored and sometimes lighter textured material. The structure is usually rather friable. These soils generally occur as flat or depressed areas or "basins" bordering the Sacramento River,



FIG. 1.—ALMOND ORCHARD NEAR CORNING ON A FAVORABLY SITUATED AREA OF TEHAMA SILT LOAM.



FIG. 2.—SCENE NEAR COLLINSVILLE FROM SACRAMENTO RIVER.

[Low areas of Muck and Peat in foreground. Montezuma Hills in distance occupied by soils of the Montezuma series.]



or as islands along its lower course. Drainage is naturally very poor and much of the series is subject to overflow or is covered with standing water for several months each year where not reclaimed. Alkali affects the margins of some of the basins, but is not normally a serious factor. These soils are derived from a wide variety of rocks and were deposited in the flattest parts of the valley as fine sedimentary material.

#### SACRAMENTO CLAY LOAMS.

*Description.*—The Sacramento clay loams generally consist of a dark-gray, drab, or black, smooth-textured, rather friable silty clay loam, often extending to a depth of 6 feet. Where the soil is less than 6 feet deep it may grade into subsoils identical with the Sacramento clays or like them become lighter colored with depth. The color of the grayer phases becomes much darker or black when wet. A light silty phase, approaching a silt loam or loam, and constituting a slightly elevated apron, often closely borders the river or slough ways which traverse the area. In certain places the soils as mapped include some marginal areas which are distinctly lighter in color and would have been mapped as the Columbia series had their size permitted separation. The soils of the group are usually quite friable where well drained and tilled.

They include small undifferentiated areas of Sacramento clay loam which in general occupy the slightly lower elevations where the soil material grades into the Sacramento clays. The clay loam does not differ essentially from the silty clay loam except in texture, being of somewhat less silty character.

*Location.*—These soils occur as rather large areas lying southward from Sacramento, upon both sides of the river, and covering almost the entire extent of several large islands. Very limited areas are shown along the river course above Sacramento and certain other dark-colored areas in the alluvial flood plain of the Sacramento are recognized as belonging to this group. Some of the island regions, classed as Muck and Peat, have narrow rims of the material included in this group bordering the slough ways.

*Topography and drainage.*—The Sacramento clay loams over most of their extent are flat, but rise slightly along the river and slough courses. In this manner the island areas, at least, have a slightly dished surface with their interiors only slightly marked with slough ways, minor depressions, or artificial drainage ways. The levees by which the group is protected from overflow are located in advantageous positions near the slough ways on the higher ground, and in this manner the group is divided into various inclosed units for reclamation. Much of the group lies near or below tide level and pumping plants must be maintained for drainage of a considerable area. The water

table is usually kept at a much deeper level than under areas of the Muck and Peat soils.

*Utilization.*—The soils of this group were not originally wooded except along the higher and better drained margins. A heavy tule growth covered much of the land but it has long been cultivated and is a heavy producer of many crops. Chief among these are alfalfa, tomatoes, melons, asparagus, celery, onions, potatoes, and many other truck crops. The better drained phases are especially adapted to pears, cherries, peaches, prunes, hops, and many other highly specialized crops.

#### SACRAMENTO CLAYS.

*Description.* The Sacramento clays comprise the clay, clay adobe, and silty clay of the Sacramento series.

The Sacramento clay typically consists of a dark-gray, bluish-gray, drab, or black clay of smooth waxy structure when wet, but is rather well-granulated and friable when well drained and aerated. This material often extends to a depth of 6 feet. There are notable variations from the typical description. The large area lying east of the Sacramento River, northwest of Marysville Buttes, is lighter colored, the drab color prevailing with a general tendency to become brown in its northern extension. It is naturally somewhat better drained than most of the type and is, in addition, more influenced by the intrusion or overwash of Columbia series material. That portion of this area lying in Butte Sink is darker colored and approaches the typical. The large area occurring in Sutter Basin departs from the typical around some of the margins where a phase closely approaching the Sacramento clay loams is recognized. Some of it is likewise covered with thin layers of silt comparable to the soil material of the Columbia silt loams. On the whole, this Sutter Basin area is one of the most typical of the Sacramento clay.

The Sacramento clay adobe consists of a dark-gray or black clay ranging from 24 to 36 inches in depth. It often has, however, a brownish cast. The soil is compact and dense in character and possesses an adobe structure upon drying. The subsoil is a dark-brown clay usually grading into light yellowish brown clay at a little less than 6 feet. In many instances, surface waters coming into the basins from the plains have deposited alluvial overwash material which differs slightly from that of both the plains and basin soils. Such a condition is found all along the western edge of Yolo Basin from Maine Prairie to opposite Woodland. This doubtful margin was in most instances included with the Sacramento clays of the basin as a more brownish phase of the Sacramento clay adobe.

The Sacramento silty clay consists of a dark-gray or black, silty clay of compact structure usually 6 feet in depth. The type puddles

when wet, oftentimes becoming adobelike upon drying. The higher and better drained areas are friable and retentive of moisture.

As indicated, the dark color and heavy texture of this group most often extends to a depth of 6 feet, but as in some of that region between Sacramento and Davisville the subsoil may grade at 2 to 4 feet into light-brown, buff, or brownish-yellow material, quite similar in color to the Columbia series. In other localities, farther south, the black clay subsoil may be exceedingly high in organic matter and approach Muck and Peat in character. The members of the group are usually high in humus and well supplied with lime, which with aeration makes them very friable.

Some of the smaller areas in the upper Colusa or Mormon Basin localities merge with the contiguous Columbia soils and the same may be said of all contacts with the Columbia series. The margins of the various basins occupied by this group merge with the plains soils and sharp transitions are rare.

The following table gives the results of mechanical analyses of samples of the soils and subsoils of the Sacramento clays:

*Mechanical analyses of Sacramento clays.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Sacramento clay:								
20734.....	Soil.....	0.0	0.5	0.7	3.4	1.8	41.0	52.7
19188, 19190.....	do.....	.1	.7	.9	3.3	1.4	41.2	52.3
19189, 19191.....	Subsoil.....	.1	.5	.3	1.4	.5	46.6	50.4
Sacramento clay adobe:								
19117.....	Soil.....	.0	.4	.3	4.0	3.0	46.9	46.3
19118.....	Subsoil.....	.0	.3	.4	6.1	7.3	48.5	38.3

The following samples contained more than one-half of 1 per cent of calcium carbonate ( $\text{CaCO}_3$ ): No. 19188, 1.84 per cent; No. 19189, 1.62 per cent; No. 19191, 0.88 per cent.

*Location.*—The Sacramento clays occupy several very large and important areas in the main valley trough from near the Marysville Buttes to the southern edge of the survey. Those characteristic low-lying basins bordering the slightly elevated main river course are largely occupied by this group. Colusa, Sutter, American, and Yolo Basins are practically coincident with the areas of Sacramento clays and include by far its greater acreage. There are a few other isolated bodies, some of the larger of which lie on the east side of the valley westward from Galt and Lodi.

*Topography and drainage.*—Except for very minor variations, the surface of this group is uniformly flat. There are a few scattered knolls, small lakes, and sloughs, but they do little to relieve the flat and uniform topography. The drainage of the entire group is very

poor, except where artificially supplied. The basins in which these soils lie are often flooded for several months each year. The soils nearly always occupy the lowest positions, receiving run-off from the plains, and overflows from the main rivers. Drainage is difficult but portions of the group are now protected by large levees with open drainage ways, the excess waters being pumped off. Much larger tracts lie outside the areas of levee protection but their reclamation is now being extensively undertaken.

Frequent inundations of the lowest parts of this group have prevented the accumulation of alkali over most of its extent, though marginal areas of intermediate elevation sometimes contain enough to prevent crop growth. The clay adobe member is most likely to show an accumulation of alkali salts.

*Utilization.*—The soils of the group are treeless, but are often covered with a dense tule growth to the exclusion of all other plants. Lesser growths of cockle bur, bur clover, smartweed, and mint occur in other localities. Salt grass is prominent on the alkali areas.

Only a small part of the group is tilled at this time owing to adverse conditions of overflow and drainage. It is mostly utilized for sheep pasture. The portions now reclaimed and farmed are used for grain, beans, sorghum, Egyptian corn, alfalfa, broom corn, and a few other crops. The yields are good wherever drainage is maintained. Irrigation will be necessary for the profitable returns of most crops. Deep plowing and aeration are important factors in the handling of these soils. Fruit growing is not yet successful. The group seems to be especially well suited to dairying and hog raising.

#### CAPAY SERIES.

The soils of the Capay series are typically dark gray and the Yolo soils with which they are associated are typically brown. It is recognized, however, that as mapped the former series includes areas of dark brownish-gray or dark grayish-brown color. Compact structure and plastic clayey textures are the rule, and drainage is much poorer than on the adjacent Yolo soils. The subsoils are light brown or yellowish brown, and free from hardpan. These soils are alluvial, being derived from a wide variety of rocks in the Coast Range and laid down as alluvial-fan deposits over flattened areas of low gradient.

#### CAPAY CLAYS.

*Description.*—The Capay clays include the clay and clay adobe of the Capay series largely as they were mapped in the earlier detailed survey of the Woodland area.

The Capay clay typically consists of heavy, tenacious clay of dark-gray or dark grayish-brown color, grading at about 36 inches into a light-brown or yellowish-brown clay of heavy, compact structure.



Although the type does not closely resemble the clay adobe member of the series it becomes plastic when wet and requires careful handling.

The Capay clay adobe consists of about 2 or 3 feet of heavy clay of compact adobe structure and of about the same color as the Capay clay. The subsoil resembles that of the clay, being like it in color and of heavy, compact structure. Lighter textured material may underlie the type at about 6 feet. The soil becomes very hard and compact and has its adobe structure highly developed when dry.

The group is normally free from gravel or angular rock fragments, but contains rather a high percentage of coarse sand. Both soil and subsoil are rather dense and require careful methods of handling. The friable, granulated structure so characteristic of the Yolo series is not typical of this group, and the soils are not so well adapted to dry farming. Certain variations from the soils as they typically occur are noted in scattered areas located near the margin of the adjacent plains and basin soils.

It is recognized that the Capay series as mapped includes soils similar in color to the Yolo series, but the former series is considered as typically embracing the darker gray or dark brownish gray material.

The Dunnigan clay, a rather indefinite type recognized in the earlier survey of the Woodland area, is included in this group as a phase of the Capay clay. It most often consists of about 3 feet of heavy, dark-gray clay underlain by yellow or light-brown clay. The material is waxy when wet, with a tendency to puddle, and nearly always contains a high percentage of alkali.

The following table shows the results of mechanical analyses of samples of the soil and subsoil of the Capay clay adobe:

*Mechanical analyses of Capay clay adobe.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
21186.....	Soil.....	0.0	0.2	0.5	2.1	4.1	48.7	44.4
21187.....	Subsoil.....	.0	.6	.5	2.3	6.5	51.3	38.7

*Location.*—The Capay clays are broadly developed in the west-side valley plain on rather uniform slopes or flats extending eastward from the lower foothills between Cache and Putah Creeks. Several other areas of lesser importance occur farther north near the edge of Yolo Basin. These soils are also represented in the group mapped as the Capay and Yolo clay loams and clays (undifferentiated) south of Putah Creek.

*Topography and drainage.*—The Capay clays are quite uniformly flat surfaced, being marked by little else than intermittent drainage

ways and an occasional low stream-built ridge. Drainage is imperfect, and injurious accumulations of alkali, sufficient in amount to preclude profitable crop growth, often occur. While the soils sometimes drain rapidly, they are overflowed at times of heaviest rainfall, and in these respects are more seriously affected than the soils of the Yolo series.

*Utilization.*—Those areas which have a high alkali content are utilized for pasture and most of the remainder are dry-farmed to grain, much of which is cut for hay. The average production is less than upon the adjacent and related heavy types of the Yolo series. Under its present conditions this group is not very well adapted to the growing of fruit or other crops requiring a well-aerated subsoil, but cultivation, drainage, and careful handling may improve the soil so that rather a wide range of intensive crops will be possible.

CAPAY AND YOLO CLAY LOAMS AND CLAYS (UNDIFFERENTIATED).

*Description.*—The Capay and Yolo clay loams and clays (undifferentiated) comprise a group of soils which is subject to considerable variation, consisting largely of the Capay clay and clay adobe, and the Yolo clay loam, clay, and silty clay. These types are described elsewhere in this report in discussing the Capay clays and Yolo clay loam and clay.

*Location.*—This group occurs as one large, irregularly shaped body, comprising many square miles in the southern part of the west-side valley slopes. It is broken by many fingers of the Yolo series of soils extending into the main area. It covers nearly all the region from Elmira to Dixon, extending westward to the low, rolling foothills and eastward to the Sacramento clays of the Yolo Basin. Gradations in color are the rule along its line of contact with the latter. The group is composed of the Capay and Yolo types mentioned above, occurring in numerous small bodies, so poorly defined in this locality that their separation on the map is impracticable.

*Topography and drainage.*—In general, this group occupies a gently sloping plain with a gradient rather less than the average of that of the slopes of the west side of the valley. The surface is usually flat, and where receiving the run-off from the hills to the west large areas are sometimes flooded. Extensive areas of these soils are badly affected by alkali. A "hog-wallow" surface is encountered in some of the alkali areas. The drainage channels marking the surface of the group are of two classes, those occupying slightly elevated ridges constructed from material deposited by flood waters, and those which are more erosional in character, carrying water which flows from the channels of the first class toward the basin and serving to drain the flatter areas upon the subsidence of the floods.

*Utilization.*—The native vegetation consists of grasses, with some tree or shrub growth along a few drainage ways. These soils are

devoted to grain farming, pasture, and grain hay production. While scattered fruit trees, largely figs, are grown near some of the ranch houses on the poorly drained clay members of the group, commercial orcharding is confined to the clay loam areas or the best drained phases of the clays. These better soils are largely confined to the region along or west of the Southern Pacific Railroad. Elmira is situated upon one of these more elevated better drained phases. Alfalfa is produced in a small way with irrigation by pumping. There are a few vineyards on these soils.

The Yolo members of this group are utilized north of Putah Creek for a rather wide range of crops, and the soils of this series within this group can be utilized for the same crops wherever drainage and frost conditions are as good as those prevailing in that section. The Capay clay soils of this group are suited to about the same crops and have the same limitations as in other parts of the survey.

#### SUTTER SERIES.

The Sutter soils are light gray, brownish gray, or dark gray, often 6 feet deep, but when of less depth are underlain by grayish, brownish, or yellowish, heavier textured subsoils. They are alluvial soils derived from andesitic tuffs and breccias or from massive andesitic rocks. They are distinguished from the soils of the related Vina series by color. So far as mapped, they occur only around the base of the Marysville Buttes. Small alluvial bottoms of minor intermittent streams issuing radially from the Buttes broaden into alluvial fans which merge to form an outwash slope encircling the rocky perimeter of this old volcanic cone. The lower margin of the soils is sometimes influenced by back water from areas of poor drainage occupied by other series, but they are normally friable, well drained, and retentive of moisture. Sandy loam and loam textures prevail, with minor clayey types of refractory structure. The series is largely undeveloped except for grain production, although some profitable dry-farmed almond orchards and other intensive developments have shown that the soils may be utilized for such purposes.

#### SUTTER LOAMS.

*Description.*—The Sutter loams include the loam and sandy loam types.

The Sutter loam typically consists of 18 inches to 6 feet of light-gray or light brownish gray sticky loam, often carrying fine angular gravel or grit. The subsoil when not similar to the soil in color and texture may be either a brown loam or clay loam more compact than the surface soil. Where the outer edge of the type merges with the Stockton clay adobe the subsoil may be black and very clayey.

The Sutter sandy loam consists of 30 inches to 6 feet or more of light-gray, brownish-gray, or more rarely, dark-gray sandy loam.

The latter color, however, is not typical. Where less than 6 feet deep it is underlain by a brownish or yellowish loam of sticky but rarely compact character. Quantities of small, sharp, angular rock fragments often occur in the surface soil.

The group as a whole is easily tilled and highly retentive of moisture, the sandy loam being especially so. These soils differ in color from those of the Vina series which are similar in origin and mode of formation, but some inextensive phases of brown color approach the latter series.

The following table gives the results of mechanical analyses of samples of the soils and subsoils of the Sutter loams:

*Mechanical analyses of Sutter loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Sutter loam:		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
20759.....	Soil.....	1.5	5.2	5.4	13.5	11.8	37.9	24.8
20760.....	Subsoil.....	1.9	5.8	7.0	17.1	13.1	29.5	25.6
Sutter sandy loam:								
20758.....	Soil.....	4.6	11.5	6.8	24.3	14.4	24.3	14.1

*Location.*—The soil group occupies irregular shaped areas around the outer edge of the Marysville Buttes and in the small valleys and coves of these hills. It sometimes extends directly to the base of the hills, but usually forms the outer portions of the fans with other soils intervening between it and the rocky central part of the Buttes.

*Topography and drainage.*—The Sutter loams have a rather uniformly good slope and are well drained by a few streams radiating from the Buttes. Small portions along the outer margins at the line of contact with the Stockton clay adobe and the basin soils are subject to overflow in periods of high water. A slight tendency toward a "hog-wallow" surface configuration sometimes marks the outer portions of the loam member.

*Utilization.*—Nearly all the group was at one time covered with a dense growth of oak, but this has largely been removed as farming has extended. Grain growing still constitutes the main industry upon the group, some of it being cut for hay. Some of the more extensive areas are pastured. Excepting a few scattered fields of alfalfa and small areas devoted to almonds and other orchard products, the group is not returning the revenue it should. All of these crops yield profitably under favorable conditions and the area devoted to them could be extended.

The growth of individual fruit trees around farmhouses and the success had with small fruits give evidence of the adaptation of the soil to a number of valuable crops. Increasing attention is being given the almond industry. The yields are abundant and no crop

failures are recorded. Irrigation is required to secure the best yields of all crops, and where practiced water is obtained by pumping from wells. The sandy loam type is moderately well adapted to the growing of crops without irrigation, and good yields of alfalfa and alfalfa seed are obtained. The group is also well suited, especially when irrigated, to the production of peaches, olives, and stone fruits, figs, grapes, berries, and melons.

#### SUTTER CLAY LOAM ADOBE AND CLAY.

*Description.*—This group comprises the Sutter clay loam adobe and the Sutter clay.

The Sutter clay loam adobe often has several inches of a brownish-gray loam on the surface. Usually the soil is a brown clay loam with pronounced adobe characteristics. In some cases the usual brown color grades into a very light brown or brownish yellow below 36 inches.

The Sutter clay typically consists of a few inches of brownish-gray loam, underlain by a sticky clay, browner than the surface soil, and becoming more yellowish as the deeper subsoil is reached.

This group of heavy Sutter soils is browner than the lighter loams and in its darkest phases closely resembles the Vina series. The group is less easily tilled than the Sutter loams and is not so retentive of moisture.

In the following table are given the results of mechanical analyses of samples of the soils and subsoils of the Sutter clay loam adobe and Sutter clay:

*Mechanical analyses of Sutter clay loam adobe and clay.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Sutter clay loam adobe:								
20766.....	Soil.....	1.0	5.1	4.3	14.2	8.0	41.7	25.8
20767.....	Subsoil..	1.4	8.8	7.0	18.4	8.2	27.0	29.3
Sutter clay:								
20763.....	Soil.....	1.1	4.6	4.3	9.9	11.2	29.6	39.2
20764.....	Subsoil..	.3	5.0	10.9	15.7	13.6	31.5	22.9

*Location.*—The total extent of this soil group is small. One area of the Sutter clay occurs about 2 miles west of Sutter. Several small irregular areas of the clay loam adobe occur in the small valleys around the southern part of the Marysville Buttes.

*Topography and drainage.*—The surface of this group is rather uniform with fair slope and good drainage, except that the lower lying areas of the clay type are subject to annual overflow from backwater in the Sutter Basin. Occasional stream washes mark the surface.

*Utilization.*—Grain and grain hay are practically the only crops produced upon these soils. Alfalfa and some varieties of grapes would possibly succeed without irrigation upon the moister phases, but the average yields would probably be low. With irrigation these soils would probably produce alfalfa, grapes, pears, figs, beans, and sorghum and, where frost conditions are most favorable, citrus fruits.

#### STOCKTON SERIES.

As encountered in this survey, the soils of the Stockton series are dark gray to black and prevailing heavy and sticky. A black clay adobe predominates. Gravel or even an appreciable quantity of sand is rare. The material is waxy and plastic under wet conditions, cracking and checking into hard flinty fragments upon drying. At variable depths, usually less than 3 feet, the soil is underlain by calcareous subsoils, ranging in color from buff or light brown to brownish yellow. Small calcareous concretions or pellets are common in the subsoil material and a well-developed calcareous hardpan often extends downward for several inches from the contact of soil and subsoil. The hardpan is variable in character and may consist of insignificant crusts or semicemented layers, or may fill the entire subsoil as an impervious mass. The surface is usually even or remarkably flat and the soils are subject to overflow. The general drainage is sluggish, the soils consisting of alluvial or semibasin sedimentary deposits, laid down in low areas of stagnated drainage. The parent material is derived from a wide variety of rocks.

#### STOCKTON CLAY LOAM.

*Description.*—The Stockton clay loam typically consists of a dark gray or black clay loam of rather compact, dense structure. When dry the soil is often quite gray, but it is darker in color or black when wet. It is usually fairly high in humus. The tendency toward an adobe structure appears at times, especially along its contact with the clay adobe of the same series. The soil is rarely or never 6 feet deep, grading at 24 to 36 inches into a light yellowish-brown or yellowish-gray compact clay loam which extends to a depth of 6 feet or more. There is a well-developed calcareous hardpan between the soil and subsoil over a part of its extent, and calcareous concretions and thin seamy layers are present elsewhere.

*Location.*—The Stockton clay loam does not occupy very extensive areas. Its largest body south of Lodi comprises a few square miles. Several other areas are encountered in the southeastern part of the survey along the lower margin of the plains soils as they reach low elevations, bordering the basin or depressed valley center. The area south of Lodi occurs along the lower edge of the Hanford fine sandy

loam delta, and merges on the other side with the Stockton clay adobe. Gradation zones usually mark its contact with all types.

*Topography and drainage.*—The type forms very gently sloping to flat areas dissected somewhat by intermittent stream channels. Drainage is fair in general, but is poor in the flatter parts.

*Utilization.*—The greater part of this type is utilized for grain or hay production, some of the more poorly drained areas being used for pasture. In some areas the fruit industry is fairly well developed. Water is extensively pumped for irrigation. Alkali decreases the value in some places, where conditions are favorable for its accumulation, but intensive development is practicable over a large part of the type. Alfalfa, grapes, and some of the hardy tree and bush fruits can be successfully grown under proper methods. The best drained phases are by far the most valuable.

#### STOCKTON CLAY ADOBE.

*Description.*—The Stockton clay adobe consists of a dark-gray to black clay, which is very sticky and waxy when wet, and filled with cracks and checks when dry. This is one of the most pronounced adobe-structured soils in the area, and this characteristic is uniformly developed in all cases except in small areas which are in a permanently water-logged condition. The humus content is apparently quite high, as indicated by the color of the material. Gravel and bowlders, or even sand, are rarely present in appreciable quantities, the type mainly consisting of as nearly pure clay as is ordinarily found. It would be practically impossible to till this soil, were it not for its adobe structure.

Butte Creek has deposited a narrow strip of yellowish silty material along its course through this type. This strip is rarely more than one-fourth or possibly one-half mile in width, and is often plainly defined as a thin overwash, the typical black clay occurring at depths of a few inches. This overwash material greatly influences tillage, however, by making the texture lighter. Cherokee Canal has built up a somewhat similar narrow belt within retaining levees, the overwash consisting of a yellowish silty deposit derived from mining operations. A continuous strip extends to the upper part of Butte Sink and modifies a small area of this type.

At depths ranging from 16 to 36 inches the dark-colored surface soil grades into lighter colored clays of buff, light-brown, brownish-yellow or yellowish color, which in places become somewhat lighter in texture, grading at about 72 inches into a loam or clay loam. The subsoils of this type are distinctly calcareous, and over most of the type a well-defined calcareous hardpan occurs between the soil and subsoil. The character of this hardpan is extremely variable.

The northern extension of that broad body north of the Marysville Buttes does not have a hardpan, but calcareous nodules and seamy layers occur. These rarely influence the agricultural character of the type. Farther south toward the Buttes these semicemented layers are more numerous, thicker, and much more highly indurated, and nearly all that country lying northwest and west of Biggs and Gridley has well-defined hardpans and semicemented calcareous beds within short distances of the surface. This condition prevails throughout the type except in small areas such as that south of Dayton.

Where the calcareous hardpans are most highly developed, the subsoil is a gray mass. In other places they grade downward into the normal subsoil of the type. The cemented layers vary in thickness from insignificant crusts to masses several feet in thickness. In general, the type has a hardpan of sufficient thickness and hardness to influence its agricultural use.

The following table gives the results of mechanical analyses of samples of the soil and subsoil of the Stockton clay adobe:

*Mechanical analyses of Stockton clay adobe.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
13066.....	Soil.....	0.5	1.3	2.0	12.3	17.9	35.0	30.9
13067, 13068.....	Subsoil.....	.5	1.6	2.1	17.1	20.3	34.4	23.7

*Location.*—The Stockton clay adobe occurs as a broad flat area north of the Marysville Buttes, and extends in an irregular manner along their east side for some distance southward. It is most uniformly and typically developed in this region, but there are several other areas along the east side of the valley. A rather large area occurs in the vicinity of Pleasant Grove, and another at the edge of the survey in the southern part. Other areas lie several miles south of Sacramento.

*Topography and drainage.*—The surface of the Stockton clay adobe is prevailingly level or flat. It follows the general slope of the region, and is traversed by numerous small streams. The greater part of the type is overflowed during periods of high water. The large body north of Marysville Buttes is at times completely inundated by the water from numerous creeks or breaks in the Feather River levees. Since it ordinarily occupies low positions at the foot of the valley slopes, the type receives considerable run-off from other areas. There is apparently little or no tendency toward alkali accumulation except around the margin of Butte Sink and in a few other areas in similar positions. Obstructed surface drainage with little opportunity for passage of water downward is the rule.



*Utilization.*—For many years this type was used only for grain farming, with some hay and pasture land. Yields of grain were highest during dry years. Recently, however, the type is receiving greater attention. Alfalfa can be grown on all the deeper phases with irrigation and protection from overflow. Some varieties of fruit and grapes can be grown successfully on the most favorable phases. Recent experiments have demonstrated that the type is well adapted to rice, and this has become an important crop in the large area near Biggs and Gridley. It is probable that the area devoted to this crop will be greatly extended. Recent increase in the value of the Stockton clay adobe is largely attributable to its adaptation to this crop.

#### LAGUNA SERIES.

The soils of the Laguna series are typically gray to light gray, often appearing brownish when wet. The darker colored clay adobe included with the series in this survey is regarded as not typical, and in a more detailed survey would probably be recognized under a distinct series head. The soils are normally compact and the subsoils vary little from the surface soils, except that they are usually heavier textured. The series is typically free from hardpan but cemented layers may occur. Some areas are subject to overflow and subsurface drainage is sometimes slow. These soils are alluvial in origin, being derived largely from the soft sedimentary rocks yielding the soils of the Arnold series. While contiguous soils have no doubt somewhat influenced their formation their gray color is doubtless due to the rocks mentioned.

#### LAGUNA LOAM AND CLAY LOAM.

*Description.*—This group of soils includes the loam and clay loam types of the Laguna series.

The Laguna loam is predominantly a sticky loam free from gravel or coarse material. The type is usually gray or light gray when dry but often shows a brownish tint when wet. It is normally compact, with a low content of organic matter, and is rather hard to till. Little variation is noted in soil and subsoil, although heavier textures are sometimes encountered with depth, the material becoming a clay or silty clay within 6 feet. The type is not considered as having hardpan or cemented layers in its typical occurrence, but the gray cemented beds accompanying and giving rise to the Arnold loams may occur in this type along contact with that group. In other places the deeper subsoil layers may be very compact and tend to reduce the movement of water. A very important variation from the typical occurs just northeast of Clements where a portion of the marked terrace was classed with an alluvial bottom of this type which joins it. The soil here is deep and exceedingly friable and it

is recognized that this phase is much superior in crop value to most of the area covered by the group.

The Laguna clay loam consists of a sticky, rather puddled or compact clay loam, normally free from gravel. The subsoil occurs as a compact and impervious clay or silty clay to a depth of 12 to 30 inches.

*Location.*—The group is rather inextensive. There are several long, narrow strips northeast of Sacramento along minor streams traversing the plains region, the soils here being somewhat brownish gray rather than gray. Another important area lies northeast of Galt and with the one mentioned above near Clements makes up the greater part of the group.

*Topography and drainage.*—The group occurs as small alluvial bottoms lying along minor streams which in most instances head near the margin of the lower foothills. The surface is smooth and is composed for the most part of irregularly shaped flats bordering the minor stream ways which meander through the types. A tendency toward hog-wallow features of surface is often found in the areas removed from recent stream activities. Overflow affects some of the material. The internal drainage is usually sufficient except where the soils are underlain by very compact subsoils in which case they are periodically in a water-logged condition. The soils are relatively free from alkali salts.

*Utilization.*—The group is at the present time largely pastured or dry-farmed to grain giving moderate yields. The deeper, more friable phases are capable of quite intensive development when irrigated. Protection from overflow is necessary in certain places. The deep area occurring at Clements and certain other friable areas are excellent soils and with irrigation can be made to produce alfalfa, peaches, figs, olives, grapes, almonds, bush fruits, and some truck crops. Excepting these best phases of the group, these soils have a rather low agricultural value.

#### LAGUNA CLAY ADOBE.

*Description.*—The Laguna clay adobe averages a dark-gray to black clay, with a more or less pronounced adobe structure. It varies considerably in color and depth of material. The two small areas lying in the region between Roseville and Lincoln grade at depths of 2 to 4 feet into grayish or brownish gray subsoils, or into the cemented material extending under the type from the adjacent areas of the Aiken soils. In these instances, the soil may carry some angular rock particles and coarse sand.

The type as it occurs in the extreme southeastern corner of the area is usually 6 feet in depth but has the prevailing dark color. It has good water-holding capacity and is much superior to the areas previously described.

*Location.*—The occurrence of the type as above described practically limits its extent in this survey.

*Topography and drainage.*—The surface is that of irregular alluvial bottoms, including some contiguous alluvial footslopes or residual slopes above the influence of the streams. Winding, intermittent stream ways with smaller lateral washes cross the type.

*Utilization.*—Most of the type is not farmed but is used for pasture. Some grain is grown with moderate yields. The two northern areas are rather undesirable for intensive farming. The southeastern area is capable of greater development and with irrigation, grain, hay, alfalfa, beans, and several other crops could be grown.

#### KIRKWOOD SERIES.

The soils of this series are dark gray to almost black in color and so far as yet encountered of sticky, clayey, and readily puddled character. The subsoils, often to a depth of 6 or more feet, may be similar to the soil material, but more frequently consist at the depth of 2 or 3 feet of grayish, yellowish, or brownish clay loam. The surface is flat and often subject to poor drainage or to overflow by intermittent washes. The soils are utilized for grain or pasturage. Their naturally poor condition may be improved by cultivation and drainage. The material is derived from adjacent soils representing the older valley-filling material, usually of the Redding, Tehama, or Corning series. It consists of local alluvial fan and footslope deposits around the margins of areas of the more elevated parent material or of alluvial deposits in local basins or depressions.

#### KIRKWOOD CLAY ADOBE.

*Description.*—The Kirkwood clay adobe consists of a dark-gray to almost black clay or silty clay of very smooth, sticky texture. It, at all times, possesses an adobe structure, cracking into huge blocks which are subsequently checked and subdivided into small cubes or angular fragments. The type is puddled and sticky when wet and exceedingly hard and compact when dry, rendering it a soil of poor tilth and refractory character. The subsoil may be similar to the surface soil to a depth of 6 feet or more or it may occur below 2 or 3 feet as a less impervious clay loam of yellowish or brownish color. In a few instances the semicemented coarse-textured subsoil of the contiguous Corning gravelly loam may underlie the type at several feet or occasional gravelly beds may supplant the ordinary subsoil. A few sloping areas with brown soil and subsoil and with drainage better developed were included in this type as mapped. This phase would be considered as belonging to another series if of sufficient extent to be differentiated. Some of the type northeast of Willows also includes some brownish areas of poorly defined character regarded as remnants of adjacent soils.

*Location.*—This type is rather inextensive, occurring as several scattered areas between Hamilton and Richfield with its greatest development in the region northeast of Willows. It is a west-side type, occurring in association with the Corning and Tehama series.

*Topography and drainage.*—The type is level or very gently sloping and in general occupies local flats or depressions of defective drainage. A water-logged condition often prevails owing to the difficulty with which water percolates through the soil, and the fact that it often receives run-off from higher bodies. Much of it is overflowed by the minor streams of the flats and depressions. The slightly higher phases are sometimes fairly well drained. Alkali at times is present in damaging amounts.

*Utilization.*—The type is utilized almost entirely for dry-farmed grain and for grazing. Very little development is possible without both drainage and irrigation. Its poor tilth can be much improved under cultivation, and it can possibly be made to produce alfalfa and general farm crops with moderate success. Pears and a few other kinds of fruits might be grown on the best phases where drained and irrigated. Typically it is not a good fruit or truck soil.

#### ELDER SERIES.

The soils of the Elder series are usually dark gray to drab, or black when wet. They are usually friable and retentive of moisture but the lighter members may carry quantities of dark-colored waterworn gravel and possess variable subsoils of loose, porous structure. The series represents rather recent alluvial material derived largely from metamorphic rocks and occupies flood plains, lower terraces or alluvial fans, with the lower portions subject to overflow. Drainage is usually good. The soils naturally support a dense growth of oaks, willow, sycamore, and brush. The surface is level, or slightly ridged and furrowed by abandoned waterways and overflow channels. The heavier members are well adapted to dry-farming but are best utilized under irrigation where they become capable of supporting an intensive system of agriculture with a wide range of crops. The most gravelly or sandy members are least productive. These soils are in this area confined to the west side of the valley, largely northward from Orland.

#### ELDER SANDS AND GRAVELLY SANDY LOAMS.

*Description.*—This group of soils comprises the fine sand, sandy loam and fine sandy loam, and the gravelly sandy and fine sandy loams of the Elder series.

The Elder fine sand consists of 3 to 36 inches of gray to dark-drab fine sand, underlain by sand and gravelly layers extending to 6 feet or more. The material is subject to great variation and frequently carries an excessive amount of gravel.

The Elder sandy loam and gravelly sandy loam consists of a gray or light-gray sandy loam to a depth of 6 feet or more. The gravelly member often carries large quantities of round or flattened cobbles and pebbles. The soil is subject to many variations, however, in texture.

The Elder fine sandy loam consists of a fine sandy loam of gray color. Like the other members of the group, it is variable, but usually carries waterworn gravel of various sizes, often in large quantities, and enough to constitute the gravelly fine sandy loam type. The subsoil to a depth of 6 feet is stratified with irregular layers of coarser alluvium.

This group includes the lightest textured members of the Elder series. The material has a wide range in texture, but usually bears moderate or excessive quantities of medium to coarse waterworn gravel throughout the soil profile. Strata of coarse and fine material may succeed one another from the surface downward in very irregular order of occurrence. A general tendency is noted for the subsoils to become increasingly coarse with depth and at many points river sand and gravel constitutes the substratum from 18 inches to 6 feet. Altogether the soils of the group are rather leachy, incoherent, and of low water-holding power. Little variation is noted in the color of the soil and subsoil, the group most often occurring as gray or dark-gray deposits quite similar in color to the Elder series in general, but lighter in color than the heavier members of the series.

The group includes within the confines of the earlier survey of the Colusa area the types previously recognized as Orland fine sand and portions of the types included at that time as phases of the Sacramento soils.

*Location.* The total area of this group is small, being confined to the alluvial bottoms of the principal west-side streams, bordering and but slightly elevated above their present channels. Some narrow strips in the bottom lands along Stony Creek and some similar ones along Thomas and Elder Creeks limit its occurrence in the area.

*Topography and drainage.*—The surface is sometimes pitted by erosion or strewn with gravel and marked by the occurrence of gravelly ridges. In addition intermittent stream ways and abandoned gullies sometimes break the otherwise rather level surface. Except during short periods of overflow the group is excessively drained.

*Utilization.*—The group naturally supports a moderately heavy growth of underbrush, small timber, or valley oak, and most of the areas lying along Elder and Thomas Creeks are as yet uncleared.

These soils are of relatively small agricultural importance. Owing to their porous, leachy character a great amount of irrigation is necessary if they are to be made highly productive. Some areas along Stony Creek are farmed, but the greater part is used for pasture.

Irrigation can be supplied by pumping from the gravelly substrata or in some instances by water from existing gravity canals. With heavy irrigation the soils return fair yields of alfalfa and various fruits, except on the most gravelly, unproductive spots.

#### ELDER GRAVELLY LOAMS.

*Description.*—This group includes soils of the Elder series having a loam or silty loam texture with a large gravel content. The soil material is usually of dark-gray color, but sometimes includes spots of yellowish or slightly reddish color, suggesting an intrusion or overwash of the material of the Tehama series. The gravel content of this group is oftentimes high, yet the interstitial soil material is usually of fine character, rendering the soil fairly retentive of moisture. It requires irrigation, however, to be made fully productive. Small undifferentiated areas of the more sandy and gravelly types of the same series were included within this group when too small to be mapped separately. The subsoils of the group are subject to as wide or greater variation than the surface soils. The loamy texture with its gravel content may extend to 6 feet or may give way at uncertain depths to rather leachy, incoherent substrata more gravelly than ordinarily found at the surface. Nearly all of the waterworn gravel conforms in character to that accompanying the Elder series, being the dark-colored, most durable remnants of the metamorphosed rocks about the upper tributaries of the parent streams. The deeper substrata of the group will nearly always be found very gravelly.

*Location.*—This group of soils is confined to elongated areas in the vicinity of Orland, lying within the present flats of Stony Creek or along actual or abandoned channels of that stream.

*Topography and drainage.*—The Elder gravelly loams are usually separated from the higher lying adjacent material of the Tehama series by a distinct terrace, but may merge with other types of the same series, or even with types of the Tehama series where the material of the group has been deposited by a tributary of Stony Creek. Drainage varies according to the relative elevation of the group above the streamway traversing the area. Except for overflow across the lower lying strips, the soils have sufficient or even excessive drainage. The overflowed portions often have a tree and brush covering, but the greater part is treeless.

*Utilization.*—Most of the group is now farmed and with irrigation is well suited to the growing of a wide range of crops, including alfalfa, and many fruits. Grain farming is its largest use.

As recognized in this survey it includes portions of types formerly mapped under the Sacramento series in the earlier survey of the Colusa area.

## ELDER SILT LOAMS.

*Description.*—The Elder silt loams include the silt loam and silty clay loam types.

The Elder silt loam usually consists of a smooth-textured, very friable silt loam, ranging from dark gray or slate colored to dark drab, becoming noticeably darker or even black when wet. The material usually extends to a depth of 6 feet without marked change in either color or texture, but at times the subsoil becomes slightly lighter colored. Gradations are the rule where it passes into other types of the same series or merges with the soils of the flood plain of the Sacramento River. In exceptional cases, the surface carries a few rounded cobbles, and gravelly beds may underlie the type below 6 feet.

The Elder silty clay loam consists of a very smooth-textured silty clay loam, or clay loam, slight variations in its silt content being common. Its color is similar to that of the silt loam, but tends toward lighter gray, as in some portions of the Stony Creek delta. The subsoil below about 30 inches may be a lighter colored, heavy, compact loam, or may continue without change of texture to 72 inches. Even a silty clay may appear as the subsoil of the heaviest phase. Gravelly substrata are usually found below 6 feet. It is less friable than the Elder silt loam, but rarely puddles and is retentive of moisture when well cultivated. A slightly sandy phase of subsoil, more permeable to water than the typical heavier types, is sometimes encountered.

The group is high in humus content as contrasted with the more elevated plains soils which border it. As noted, the water-holding capacities are good.

The following table gives the results of mechanical analyses of samples of the soils and subsoils of the Elder silt loams:

*Mechanical analyses of Elder silt loams.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
Elder silt loam:		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
24115, 24116.....	Soil...	0.0	0.2	0.8	16.9	17.1	55.4	9.7
Elder silty clay loam:								
24119.....	do.....	.1	.2	.4	5.9	17.1	56.6	19.5
24120.....	Subsoil..	.0	.3	.4	9.0	31.8	38.3	19.9

*Location.*—This group of soils occurs as several rather extensive areas lying along Elder, Thomas, and Stony Creeks, and as with the other soils of this series is confined to the west side of the Sacramento River. The most representative body of the silt loam member lies around Richfield as the rather broad, alluvial bottom of Thomas

Creek. The silty clay loam member occurs in areas of medium extent along Stony, Thomas, and Elder Creeks. The largest areas lie on the south side of the latter stream and within the lower part of the Stony Creek delta in the vicinity of Hamilton City. The soil near the latter place was formerly included as a phase of the Sacramento silty clay loam in the earlier survey of the Colusa areas.

*Topography and drainage.*—The surface is usually level and without many minor irregularities to decrease the value of the soils for farming. It is slightly marked by shallow remnants of winding waterways, former overflow channels, or by the courses of minor drainage ways entering the main body of the group from lateral territory. Those areas lying up stream from the general locality of the Sacramento alluvial plain occur as rather well-defined, low terraces or alluvial bottoms. As the valley trough is approached, and the regional slope becomes less, the soils occur as alluvial fan or delta material, the area around Hamilton City being a noteworthy example. Practically all of the lighter areas are well drained, being usually sufficiently elevated to escape overflow and possessing no indurated layers to arrest the percolation of surface water. There are some puddled areas of deficient drainage, but their total extent is small.

Drainage is generally well established on the silty clay loam member of the group, but occasional overflows may occur locally, and sub-drainage, owing to the heavier, more compact condition of the subsoil, is somewhat sluggish. Where lying adjacent to heavily irrigated districts, there may be some possibility of accumulation of excess subsoil waters or a high water table which may require artificial drainage. Some of the Stony Creek areas merge with the slightly more elevated bordering series, but those along Elder and Thomas Creeks have distinct boundaries marked by terrace lines.

*Native vegetation.*—The group was originally covered with a rather heavy growth of vegetation, including valley oak. In this respect it contrasts strongly with many other soils of the area.

*Utilization.* This group comprises first class agricultural soils the most of which are utilized at this time. Dry-farmed grain in point of acreage continues as the principal crop, with heavy yields under an extensive cropping system. A great deal of the area covered has been transformed in recent years from dry-farmed grain ranches to intensively farmed irrigated districts, and large quantities of sugar beets and alfalfa are already being grown. Only some of the flatter, poorly drained spots are unsuited to intensive cultivation. There are some old orchards upon the group and all give good yields under irrigation. Many new orchards are being planted, and these soils are coming to be recognized as some of the best in the valley. Fruits, nuts, alfalfa, sugar beets, berries, and truck crops return profitable yields where irrigated. Irrigation is practiced on certain portions of



the group by the use of ditches and of water pumped from gravelly substrata. Something has been done in the development of the group in fruit culture without irrigation, but the increased yields following the use of water more than justify even the heavy expense involved.

#### WIND-LAID MATERIAL.

##### OAKLEY SERIES.

So far as observed, the soils and subsoils of the Oakley series are brown in color and of sandy texture. They are composed largely of wind-laid material derived from sandy deposits in the adjoining river delta region. Only one type, the Oakley sand, was encountered in this area.

##### OAKLEY SAND.

*Description.*—The Oakley sand consists of a brown, medium-textured sand. It is nonmicaceous, low in organic matter, and of a rather loose structure. While the subsoil is usually similar to the soil to a depth of 6 feet or more, it is in places rather loamy and of a better water-holding capacity. This is often true where the type grades into adjoining soils or where it is spread as a rather thin veneer over their surface. Considerable fine material gives the sand a loamy consistency in the smoother areas. Gravel, bowlders, and rock outcrops are absent. The soil, while very friable, is rather retentive of moisture and responds readily to applications of organic matter. The deeper underlying material is usually that of the Antioch series.

*Location.*—This type is confined to the south edge of the area, the main body bordering the San Joaquin River east of Antioch. Smaller detached bodies lie a little farther east, and to the northeast some groups and islands of it occur within extensive tracts of the group of Muck and Peat soils. Its extent is relatively small.

*Topography and drainage.*—Closely bordering the river bank for some distance eastward from Antioch are some high typical dunes which would have been recognized as Dunesand had the area covered been sufficient to differentiate on the map. Aside from these high dune hills, the surface of the type is smooth, slightly uneven, or gently rolling, showing at all times the effects of wind-modification of the surface. Inclosed local depressions are numerous, sometimes having marshy bottoms. Drifting occurs in places, but usually it is not serious. Drainage is mainly by percolation, run-off rarely occurring.

*Utilization.*—Under natural conditions this type supports a scanty vegetation. It is partly utilized for the production of grain, almonds, grapes, asparagus, and peaches by dry farming, with medium to light

yields. Under irrigation even the more porous areas can be made to produce successfully these and other crops, including early-maturing truck crops. The dunesand phase is of little value for agriculture and is utilized largely as a source of sand for building.

#### MISCELLANEOUS MATERIALS.

##### MUCK AND PEAT.

*Description.*—The Muck and Peat group of soils covers the greater part of what is known as the "Island" region. The material is slightly variable in character but is largely composed of organic matter in various stages of decomposition. It typically consists of 6 feet or more of partially decayed vegetable matter and undecomposed plant roots and stems in a fibrous condition, mixed with varying quantities of alluvial silts. The surface few inches generally consists of a black muck of pasty consistency when wet and of great water-holding capacity. This is underlain by a brown, more fibrous, peaty material extending to depths of several feet. The typical black color of the surface is sometimes modified by a thin overwash or veneer of river silts or fine sands, giving it a grayish or brownish appearance. Where this group approaches other types, it is sometimes underlain at depths of less than 6 feet by clay loams or other compact river sediments. The Muck and Peat material varies widely in total depth, and while much of it is underlain at depths of less than 10 feet by silt or sand, it extends in large areas to much greater depths. Only the immediate crust is of sufficient solidity and toughness to bear the weight of farm animals or machinery, the underlying material being spongy and very unstable. Even where reclaimed, the water table is usually encountered within 24 inches of the surface.

Although quite sticky when wet, there is but little or no tendency toward puddling, the surface being friable and easily tilled after the first cultivation succeeding reclamation.

Over a phase of this group in important areas an overwash of mineral matter has been deposited to depths of one to several inches. In other places this order is reversed, the Muck and Peat material being underlain at depths of a few inches by sediments.

Some areas of this group near Suisun and Honker Bays support a brackish or salt water vegetation, with many large areas of the typical tule growth. Some of this region varies from the typical in having a surface covering of sands and silts. The saline character of parts of this phase is due to brackish or salt waters, entering through a network of tidal sloughs. Large quantities of fresh water are periodically discharged upon the surface of these flats, which tends to reduce the salinity in many areas.

*Location.*—The Muck and Peat group covers a wide area in the southern part of the survey near the confluence of the Sacramento and San Joaquin Rivers and extending for some distances up their courses. Considerable areas of this group occur south of the limits of this survey.

The group occupies flat areas ranging in elevation from a few feet above sea level to 10 or more feet below (see Pl. III, fig. 2). The San Joaquin and Sacramento Rivers enter this great depressed region and pass through it by very tortuous courses. In addition, a great number of meandering sloughs or distributaries net the surface connecting with the lower courses of the large streams. These divide the group into a great number of large and small islands. Various parts of this island tract have been developed through reclamation, levees being constructed along the streams and sloughs to protect the land from overflow. In those areas lying below tide level it is necessary to pump the water out over the levees and to drain the land by the construction of ditches and the operation of pumps. Some of the islands which were reclaimed and for many years have returned to a flooded state as a result of the breaking of the levees in times of very high water. Other tracts have recently been reclaimed, and still others are in process of reclamation. All areas which are known to be predominantly Muck and Peat are shown upon the map as that class whether reclaimed or submerged. The reclaimed areas have a characteristically flat surface with a general tendency to dip slightly towards the middle of the island. In fact, many of the islands are bordered along the enclosing sloughs by slightly elevated marginal bodies composed of soils sufficiently high in mineral matter to be classed with the Sacramento or Columbia series. The Muck and Peat group can be drained only by pumping, except in small areas well above tide level.

In the construction of the earlier levees rather crude methods were usually employed, but through modern engineering methods they have been greatly improved. Large dredges are now utilized, and the usual practice is to place the levees farther back from the sloughways and streams than originally. Much trouble is caused by the settling of the levee, because of its weight upon the unstable deeper layers. This often necessitates the continual addition of material to the levee crown until a fair degree of stability is attained. With cultivation and drainage the land also settles considerably, so that the maintenance of levees or their reconstruction in case of destruction by floods becomes increasingly difficult. In the case of Bouldin Island, which was long farmed and eventually abandoned because of enormous breaks in the levee, reclamation is especially difficult because of the settling which took place during the farmed period.

The average cost of reclamation varies considerably, but such work is ordinarily warranted by the profits derived, wherever the reclamation of the tract is not attended with unusual engineering difficulties. Permanent pumping plants are usually maintained along the levees to keep the reclaimed districts free from surplus water.

*Origin.*—Muck and Peat are essentially the more or less decomposed products resulting from the growth of aquatic plants, important among which is the round tule. Extreme lightness in weight is a striking feature of the material, large fragments frequently becoming detached and floating about in the streams. The ignition of these soils often proves troublesome in dry periods, the organic material of the soil slowly smoldering until checked. This greatly reduces its value, since a mere bed of ash remains, with increased capillary movement and rapid evaporation from the surface, resulting in the accumulation of alkali salts.

The production of special crops on Muck and Peat is carried on largely by Chinese, Japanese, Hindoos, and various other classes of labor accustomed to furnishing the vast amount of hand labor and skill necessary to the success of these crops. These special crops are usually subirrigated, water being easily derived from the near-by sloughs and large streams, which often lie at a higher elevation than the reclaimed lands within the levees. This method would prove disastrous in any soil having a high capillary movement, but in the case of Muck and Peat is not so damaging, since the alkali accumulates very slowly. Excess alkali accumulation is a serious problem, however, as it can be but a question of time when injurious quantities are concentrated in the surface few inches, if the water movement continues to be uniformly toward the surface. The effects of alkali can be counteracted in these low areas by flooding the land.

*Utilization.*—The Muck and Peat soil is poorly adapted to the growing of alfalfa or any other deep-rooted crops, owing to the high-water table which limits deep-root development. On the other hand, it is admirably adapted to certain special crops such as asparagus, potatoes, onions, beans, celery, and many other vegetables, some of which are produced in large quantities. Some forage crops, such as timothy, redtop, rye grass, and certain of the clovers, do very well.

#### RIVERWASH.

*Description.*—Riverwash is a nonagricultural type of very coarse texture, consisting of rounded or flattened gravel, cobblestones, coarse sand, and finer sediments in varying quantities. As a rule the coarse material greatly predominates, making the type leachy and incoherent.

*Location.*—Areas of this type occupy low-lying areas, strips, or islands along the principal streams and similar small areas in the beds of lateral streams. The principal bodies outside the flood plains of the Sacramento occur in the gravelly beds of Stony, Thomas, and Cache Creeks. Practically all the large streams of the east side of the valley are flanked in places by bars of this type. Many of these are too small to be shown satisfactorily on the map.

#### ROUGH STONY LAND.

*Description.*—Areas which have a very broken, deeply-dissected, precipitous, and rocky surface are classed as Rough stony land. These areas are nonagricultural, because of both their rugged and stony character, either of which in the absence of the other would render the land mainly untillable. Small patches of soil material occur, the character of which, as well as the other main features, varies largely with the character of the rock in the various areas. In the areas of Rough stony land along the northeastern margin of the survey the surface is badly dissected and the principal rocks are andesite and basalt. In some places this type includes rough cliff-like areas within the Aiken series, and the soil material closely resembles that of this series. Farther southward along the eastern edge of the survey the Rough stony land occurs in hilly localities where diabase hills and knobs prevail, and the soil material is similar to that of the Aiken series. The central part of the Marysville Buttes, consisting of massive andesite, comprises the most prominent body of Rough stony land in the area. Here a group of extremely rough and serrated peaks and ridges constitute the most mountainous phases of this type. The rock areas of this locality are practically devoid of soil accumulations.

Several bodies of Rough stony land are mapped along the western edge of the survey, where the type occurs as elevated, rugged hill slopes and ridges, extending in a general north and south direction. It is prominent in that part of the area, comprising the foothills lying west of Maxwell. The surface is broken by outcropping massive ledges of sandstones. The soil, which is very shallow, is generally of a sandy loam texture and light-reddish or brownish color, resembling the material of the Sites and Altamont series.

Rough stony land is always characterized by excessive erosion, which removes the soil material almost as fast as it is formed by disintegration. For this reason this type supports only a sparse vegetation, and barren areas are very common. In some large areas, however, tree and brush growth secure a foothold.

Rough stony land is valuable only for grazing and for the timber it supports, which is used mainly for firewood.

## TAILINGS.

*Description.*—Tailings comprise a group of materials consisting of débris from dredger and hydraulic mining operations. Gold dredgers in this area have been operated in the broad, gravelly beds and bars of several of the larger streams where they enter the valley plains. In most cases the original material would have been classified as Riverwash, or some low-lying alluvial type, passing at a depth of a few inches or a few feet into gravelly substrata. In the characteristic operation of dredging these auriferous gravels, with the entire mass of coarse alluvium, to a depth of many feet, is bodily lifted and thoroughly washed. In the progress of this work, material is deposited in heaps or ridges varying in height from a few feet to 50 or 60 feet. The general tendency in disposing of the débris from the dredgings is for the finer soil material to be redeposited under the coarser gravels, and this sorting process leaves the surface composed of a succession of barren, cleanly washed cobble heaps.

There are a few phases in which the gravel carries more than ordinary quantities of interstitial soil material. Aside from these the type is unfit for any form of agriculture.

## TIDAL MARSH.

*Description.*—Tidal marsh comprises areas of recent silt and clay sediments occurring at about sea level and in position to be inundated by daily fluctuations of the tide. It is traversed by open tidal sloughs and is practically barren. As a rule it is heavily impregnated with salt. A single area is mapped in this survey around the shallow eastern extension of Suisun Bay. It is of no agricultural importance, and is capable of reclamation only at great expense.

IRRIGATION.<sup>1</sup>

While irrigation has been practiced in parts of the Sacramento Valley for many years, it has not been as extensively developed there as in many other sections, owing principally to the general type of agriculture, the large land holdings, and to the fact that much desirable land is periodically flood swept, rendering the maintenance of permanent irrigation works uncertain. In 1910 only about 25,000 acres of the valley was under irrigation, confined mainly to small bodies of the soils of alluvial or alluvial-fan origin. Increasing attention is being given to the development of irrigation systems. Notable among the projected systems is the so-called Iron Canyon project. This is designed to utilize a reservoir site located on the Sacramento River a short distance above Red Bluff, and its effect will be to store

<sup>1</sup> See Bulletins 207 and 254, Office of Experiment Stations, U. S. Dept. of Agr., *Irrigation in the Sacramento Valley, and Irrigation Resources of California and their Utilization*, also *Irrigation in the Sierra Foothills of California*, now in course of preparation.

surplus flood waters, thus relieving, to some extent, overflow conditions and at the same time making much water available for irrigation.

As regards the supply of water, either for development by ordinary diversion or storage methods, the valley is probably the most favored section of equal extent in the arid or semiarid regions of the west. The supply appears to be considerably in excess of the actual needs, provided it is properly stored and handled.

The systems now in use have appropriated the most easily available water or are using that released by the various power plants located along the upper courses of the streams in the near-by mountains. The total annual discharge of the major streams of the valley over a period of 4 to 6 years is stated to be about 28,000,000 acre-feet. With an average requirement of 3 acre-feet for crops during the growing season, this amount would supply sufficient water for more than twice the area of cultivable land covered by this survey. Owing to navigation requirements, however, the total discharge through the valley is not available for irrigation, even though complete utilization through storage could be made feasible. Notwithstanding this, sufficient water for the needs of the entire valley is available if withheld in storage. In addition to the surface flow, there is considerable water available by pumping. Pumped water has been an important factor in the irrigation of the valley for many years and is being more and more extensively utilized, largely through improvements in pumping machinery and the extension of power lines furnishing electricity.

The most economical use of water for irrigation is made where it is supplied at a definite price per miner's inch or second-foot. Wherever water is supplied on this basis in the area little damage has been done to lower lying lands, since only sufficient water has been used to meet the requirements of the growing crops, and little has been allowed to escape by percolation. This contrasts strongly with conditions where water is supplied at a stated price per acre, under which there is usually an excessive use of water, causing injury to lower lying lands.

Some of the deeper rooted crops produce moderately well on favorable soils without irrigation, but the application of water is necessary for the best returns from practically all specialized crops. There is very little rainfall in the valley during the growing season and with the high temperatures and low humidity it is practically impossible for the soils to store and yield sufficient water for maximum production.

Alfalfa and fruits are the principal crops irrigated. Owing to the earliness of spring, it is possible to utilize the high moisture content derived by the soils from winter rains so as to mature the first and in many instances the second crop of alfalfa without irrigation.

After this one good irrigation usually with one-half to three-fourths of an acre-foot of water is the rule for each crop. At the prevailing price of water this ranges from 50 to 75 cents per acre for each crop, so that, with three or four crops to be irrigated, the cost of water for alfalfa growing usually varies from about \$2 to \$3.50 per acre annually. The cost is sometimes less than this, a great deal depending upon the texture of the soil and the preparation of the surface. The shallow hardpan lands require less water at each application than the deep soils, but their droughty nature makes more frequent irrigation necessary so that the total quantity of water used is greater.

Check and border systems are usually employed in the irrigation of alfalfa. In the former the land is divided into rectangles or into contours plots without regular size. The border system is less expensive, consisting of low levees, 40 feet or more apart, extending the length of the field. The borders or retaining banks for both systems are low and rounding and are sown to alfalfa with the rest of the field. They are best constructed where they give the least trouble possible to field machinery, and in any system for best results the land is so leveled that the water uniformly covers all parts. Poor preparation of the land has often been the rule in the past, with irregular yields the result. Poor leveling permits the water to accumulate in low places and unless it is drawn off quickly plants are likely to be seriously damaged by scalding.

Where pumping is practiced the water is usually carried from the well to the various plots or checks by means of a movable pipe line. This method appears to give satisfaction when well conducted. It permits the regulation of the quantity of water to be applied to each check and eliminates the necessity for ditches which break the regularity of the fields and occupy valuable land.

Although much of the island country west and northwest of Stockton is below stream or tide level, it needs irrigation at times to insure satisfactory crop yields. When necessary water is drawn from the river or sloughways by means of pumps, or in certain instances it is siphoned from these sources. In dry years the drainage ditches in this locality serve as distributing systems for water to be supplied by subirrigation. In such places the cost of irrigation is low. Nearly half a million acres of low basin soils along the Sacramento River have not yet been provided with irrigation and must await river improvement and protection from overflow. In the reclamation of portions of these lands from overflow it was thought that they would produce maximum yields without irrigation, but experience has shown that irrigation is necessary in most years in order to secure the fullest returns. The cost of irrigating such lands is not great and the main difficulty lies in getting the water into the soil without seriously injuring its physical condition. Alfalfa will probably always be an



important crop on these low basin soils and whatever system meets the needs of this crop will be most useful.

In some of the more level portions of the area fruits are supplied with water from open canals and by pumping. The water is carried to the orchards through laterals and there, in most instances, applied by the shallow-furrow method. From 2 to 6 shallow furrows, depending upon the age of the trees, are made between each two rows of trees and a small stream added to each furrow. Where the surface is hilly and uneven, as in the Fair Oaks and other foothill sections, water is distributed by underground pipe lines. Small iron pipes lead from the main system to the highest points of each elevation, whence the water is distributed by the landowner as he desires. The size of the stream in each small furrow depends under all systems upon the slope of the land, the length of the furrow, and the type of the soil, but usually the water is run directly down the slopes. On the steeper slopes the furrows are made with many crooks or U-shaped curves around each tree to lead the water slowly down, and thus prevent erosion. Contour irrigation is seldom used.

The quantity of water used in irrigating fruit varies considerably, depending on the kind of fruit grown, the texture of the soil, slope, exposure, humus content, and the individual practices of the grower. Three or four applications of 5 to 7 inches each have been found to give the best results. The cost of water on this basis ranges, ordinarily, from \$5 to \$8 an acre annually. In some places a uniform rate of \$3 an acre is charged, but in most instances water is sold by the miner's inch. Where water is very scarce, the deep-furrow method is used to good advantage in orchard irrigation.

Cultivation nearly always follows irrigation, but in cases where it does not weeds are allowed to grow through the summer, being plowed under for green manure at the close of the irrigating season. This method is wasteful of water, besides having other disadvantages. Owing to the differences in texture, structure, and composition of the various soils, the range in topography, and the diversity of crops grown, it is impossible to make specific recommendations for irrigation in the Sacramento Valley. Each class of soil of sufficient agricultural importance should be tested to find its water requirements for the various crops to which it is adapted.

#### OVERFLOW AND DRAINAGE.

The Sacramento Valley is so situated as to suffer much from overflows. The trough of the valley receives and conveys drainage from a rather large catchment basin, covering a little less than 20,000 square miles. The lower part of the river course traversing this area has a slight fall and is bordered by a broad, depressed belt of land. Bordering this low trough are gently sloping valley plains,

which on their lower side merge with the flat soils of the middle valley and on their upper side pass by slight gradations into the lower foothills of the mountain ranges flanking the valley. The valley depressions through this area receive run-off from this lateral territory by means of numerous streams which periodically deliver enormous quantities of water. Especially is this true of those streams issuing from the Sierra Nevada, which are burdened at times not only by rainfall but by water derived from the sudden melting of winter snowfall by warm rains. In addition, the valley receives enormous flows from the Sacramento River, delivered at the head of the valley from the extensive drainage basin lying about the upper river courses. The concentration of the precipitation into a well-marked wet season further augments the unfavorable conditions induced by the adverse topographic position of the lower parts of the valley. In addition, many of the stream courses have been rendered less efficient than they naturally were by the choking of their channels with mining debris, or "slickens," derived from hydraulic mining operations along their courses many years ago. The protection of lands from overflow and the improvement of the river courses have been a matter of first concern since the early agricultural development began.

Heavy precipitation sometimes occurs over the entire region and at such periods the valley trough suffers greatest, but in many places the plains soils are also affected by overflow water debouching from the bordering ranges. The various low-lying basins before mentioned, largely occupied by the soils of the Sacramento series and the Muck and Peat soils, suffer most under natural conditions and, where not protected by levees, remain covered with water to a depth of 10 feet or more for from one to several months. Generally speaking, the Columbia, Stockton, and Alamo series are also subject to inundation where unprotected. A great many other soils derived from alluvial, alluvial-fan, and recent valley filling materials are also affected more or less severely. For many years, levees have been constructed and maintained at considerable expense for the protection of the lower lying soils, but there still remains about one-fourth of the entire area surveyed which would be greatly benefited by such protection. Much of the area of Muck and Peat and of the soils of the Sacramento and Columbia series are now protected by levees and additional works are planned or under construction. Eventually, the flood waters will be practically under control.

Much of the region lying immediately along the Sacramento River from the Marysville Buttes southward is quite well protected by levees, with overflow ordinarily under control. As mentioned, some of the basin soils and a great deal of the island country are also protected, but there yet remain vast bodies of this depressed character

for which no protection is afforded. Difficulties are increased at all times by the fact that although the waters of the central valley be kept within bounds there are yet great volumes of water which pour into the center of the valley from numerous lateral streams. Reservoirs to hold water for irrigation and power are being constructed on some of the upper stream courses, and it is probable that a system of these judiciously located will do much to assist existing and proposed levees and by-passes to control the floods. A great deal of the valley at this time is either untilled or farmed in a haphazard manner, because of its liability to damage by floods.

Some of the bottom lands extending north along the Sacramento River from the Marysville Buttes to the head of the valley are protected from overflow by levees, but in much of that section the soils slope toward the river, and overflow and drainage in general are not so adverse as farther south. West of the Southern Pacific Railroad, southward from Chico, is a flat area of Stockton clay adobe. It lies below the general level, with a slight slope to the south or southwest, and although crossed by numerous shallow, sluggish waterways would in most cases be benefited by drainage. Much of the type is inundated for varying periods during high water.

Drainage is of especial importance for soils in arid or semiarid climates because of the danger from alkali accumulations, which usually accompany a high water table. Shallow-rooted annuals and plants with well-developed lateral root systems often do well in this area with a water table at 20 to 24 inches below the surface, where there are no harmful accumulations of alkali. Many perennial crops also thrive here for a number of years with a water table within 30 inches of the surface, especially if it does not fluctuate greatly. For best results, however, free water should be kept below 4 or 5 feet for tree fruits.

Artificial drainage has been found necessary over much of the area protected from overflow by levees, and would likewise be beneficial to much other land. There are extensive areas of nearly flat land along the western margins of the great basins lying west of the Sacramento River, which represent the lower and flatter eastward extensions of the valley plain soils where they merge with the basin soils of the valley trough. This territory ranges from one mile to several miles in width, has a nearly flat surface, and is often dotted with slight depressions, which receive the run-off and seepage waters from lands lying to the west. This results in numbers of small intermittent lakes, the water being removed by evaporation or slow percolation. In addition to the lack of drainage in this locality there is sometimes a high water table and a large accumulation of alkali. Relief can only be obtained by a drainage system of sufficient magnitude to carry off quickly the accumulated water and lower the

water table. Many other sections outside the main valley trough would be benefited by providing better surface drainage, even though alkali may not yet have accumulated.

Wherever the basin soils are inclosed by efficient levees they are usually drained by open ditch systems, even though they frequently lie at or below the water level in the Sacramento River. A canal from which small open laterals radiate to all parts of the reclaimed area is ordinarily constructed along the lowest part of the reclaimed unit leading to a sumphole near the river or to a convenient slough. The excess water is removed and forced over the levee by pumps. This system of drainage is easily maintained. It is frequently used on the basin soils, and the cost of reclamation, including the large protective levees of the unit, ranges from \$40 to \$60 an acre. This cost may seem high, yet it is more than justified by the productiveness of the soils.

Most of the island region below Sacramento is reclaimed, and although largely below tide level, the system of drainage used on the basin lands is established there. Most of the soils here are Muck and Peat.

The drainage conditions discussed above apply largely to a broad strip extending through the middle of the valley, or extending from this central belt in prongs or irregular areas into the flatter portions of the contiguous valley plains. The upland soils over the greater portion of the west side of the valley are free from hardpan and permit such rapid percolation of water that only minor surface relief is necessary. Conditions in the upland plains on the east side of the valley generally give good drainage, but the presence of hardpan often prevents the downward passage of water and numerous small depressions become water-logged during the rainy season. These features are largely discussed under the Redding, Madera, and San Joaquin series. Relief is sometimes obtained in these hardpan lands by opening passageways through the hardpan into underlying more porous beds which occur in some places.

#### ALKALI.

On account of the time necessary for a detailed study no alkali map was constructed in the reconnaissance soil survey of the Sacramento Valley. Considerable work of this character has been done in the earlier detailed surveys, however, and some additional observations were made during the progress of this survey.

On account of less irrigation, a higher rainfall, heavier soils in general, and a system of drainage ways which reaches the valley trough, there has not been so great a tendency toward the accumulation of excess alkali salts in the Sacramento as in the San Joaquin Valley, where the conditions mentioned are less favorable.

In the past only slight attention has been given to the cultivation of soils charged with alkali in the area, on account of the large available acreage of soils not so affected.

Most of the alkali in the soils of the area has accumulated under natural conditions and is not due to excessive irrigation. These soils have until recently been utilized for pasturage, but rapid increase in land values has caused some attention to be given to their reclamation, when favorably located.

There are about one-half million acres of land in the Sacramento Valley which are damaged by alkali and about 90 per cent of this occurs west of the Sacramento River. About three-fourths of the total area affected contains less than one-half of 1 per cent of total alkali salts in the surface 6 feet. The remainder is more seriously affected.

Nearly all the soils affected by alkali on the west side of the valley lie east of the Southern Pacific Railroad and correspond closely in position to the poorly drained areas discussed in the chapter on drainage. In most places over the floor of the large basins, however, alkali is absent, having been leached out by the downward movement of water left by the recurring floods. There is an irregular and almost continuous belt of affected lands along the western margin of the basins from the southern part of Glenn County to the Potrero Hills. One or two small bodies occur in local areas of restricted drainage along the foothills, but they are of minor importance. The heavier members of the Willows, Solano, and Capay series constitute the greater part of the west side alkali lands, though some parts of the Sacramento clays are also affected.

On the east side of the valley a pronounced area of alkali-affected soil occurs between the lower extensions of Butte Creek and the Sacramento River, being there confined to the Sacramento and Columbia series of soils. Aside from this, most of the alkali land of the east side occurs as an irregular margin along the eastern edge of the basin lands extending along the trough of the valley. A small affected area occurs west of Lodi along the margin of the Muck and Peat lands, being here almost coextensive with the Fresno loams, but extending to the Sacramento series also. The soils around the margin of the Sutter Basin, especially the lighter types, are more or less affected with alkali in many places. Between Cranmore and Knights Landing alkali occurs in moderate to high concentrations in the surface few inches of sandy soils, but if this were distributed through the surface 6 feet it would not usually be of sufficient concentration to cause damage to growing crops.

In the east side of the valley the alkali salts are rather uniformly distributed through the soil and the subsoil or are concentrated at the surface, but along the west side, in many places, especially where

the soils are heavy and subject to periodic overflow, the greatest concentration of salts frequently occurs at a depth of about 3 feet.

Many fairly productive fields have barren spots carrying high percentages of alkali. These spots may be few or many in number, and in all cases indicate poor drainage. They usually increase in extent if drainage conditions remain unchanged, but if the water table has been lowered sufficiently they may be reclaimed by irrigation.

Numerous analyses show that the principal salts present in the alkali of the Sacramento Valley are the sulphate, chloride, and bicarbonate of sodium. Some sodium carbonate or black alkali occurs in local spots of high alkali concentration or in small quantities with the other salts over the more extensive areas, but it seldom occurs along the west side of the valley, probably owing to the presence of calcium sulphate or gypsum in the soil-forming rocks of that section.<sup>1</sup>

#### SUMMARY.

This reconnoissance soil survey of the Sacramento Valley, Cal., covers an area of 6,274 square miles. It includes the main valley floor, valley slopes, and portions of the lower rolling or foothill areas marginal to the higher, rugged regions occupied by the Sierra Nevada and Coast Range Mountains. It does not include all the agricultural region in the Sacramento Valley, its scope being roughly confined to that part covered by recent United States Geological Survey topographic sheets. The area is of great agricultural importance and has a population of about 170,000. The Sacramento Valley is the northern extension of the great interior valley of California. With the San Joaquin Valley, covering the southern two-thirds of the interior valley, it constitutes the most extensive agricultural section of the State.

The climate of this area is an important factor influencing all present tendencies toward intensive agricultural development and must be considered in all plans for the development of a highly specialized agriculture. There is a rather uniform absence of damaging frosts, with high average temperatures without great extremes from summer to winter. The precipitation is confined mainly to the winter months, leaving the summer suited to the ripening, curing, and handling of orchard products. The region is semiarid, the rainfall varying from about 14 inches in the southern part to about 25 inches in the northern, with local variations. The mean annual temperature ranges from about 60° F to 62.50° F., these figures being comparable with those for the San Joaquin Valley, and even for points much farther south in California. Summer temperatures are high, but the low relative humidity has a universal effect of making the high tem-

<sup>1</sup> For particulars concerning the reclamation of alkali lands, see Bulletins 21, 34, 35, and 42, Bureau of Soils.

peratures less oppressive. The occurrence of killing frosts is ordinarily confined to the winter months, and thin films of ice frequently occur. The frost which affects fruit blossoms varies locally and defines the location of fruit belts. Dews and fogs occur during the rainy period. Wind, hail, and thunder storms are rarely damaging. The area appears at its best during late winter and early spring, when even the droughty soils are covered with green vegetation and wild flowers.

The agriculture of the area began about 70 years ago in a very feeble manner. Grain growing became predominant and was extended to practically all the soils of the valley. Later the fruit industries became established, and these have increased in importance and acreage, with a proportionate decrease in grain growing. Irrigation has been an important factor and is developing rapidly. The possibilities of the valley have not been even approximately developed, and by far the greater acreage is devoted to grain growing, with low profits. A wide diversity of fruits and other specialized crops are produced on a small total acreage. With the aid of irrigation, the subdivision of large holdings, and an increase in the number of farmers, the region promises to develop rapidly. The tendency is toward the production of fruit and truck crops and dairying.

The soils of the Sacramento Valley occur in great complexity. They are shown in 67 groups, including 5 miscellaneous soils and a number of undifferentiated types. These soils are closely identified with the various rock masses of the parallel ranges of mountains bordering the valley. The valley has undergone several important transitions which have had an important effect on the soils. They are broadly divided into four province groups or divisions. The residual soils from consolidated rocks, largely along the valley margins, comprise 7 soil series. The soils derived from old valley-filling material comprise 10 soil series. They largely occupy positions along the outer valley slopes or rolling areas, at elevations relatively lower than those of the residual soils. The soils derived from alluvial and recent alluvial fan deposits occupy the lower parts of the valley or the valley slopes now largely within the influence of modern streams. A wide range of soils is found within this province, and upon them the greater part of the intensive agricultural development of the region has taken place. Sixteen soil series are included in this group. The fourth division, wind-laid soils, is not extensive in this survey, and includes but one series, represented by one type. In addition there are 5 types or groups of miscellaneous character.

Irrigation has long been practiced in the valley, yet its development has not been rapid. The total supply of water available is great, although its complete utilization will necessitate storage. Many of the soils best suited to fruit production are used for orcharding

without irrigation, but it is generally recognized that irrigation is highly desirable. In many parts of the valley irrigation is the controlling factor for all crops except grain. Water can be made available for all parts of the valley only through expenditure of much money, owing to the magnitude of some of the necessary projects.

The control of flood waters is one of the most immediate problems in the agricultural development of the Sacramento Valley. Large expenditures have been made in the construction and maintenance of levees, and a fairly efficient system protects much of the valley in years of ordinary or low rainfall. Previous efforts have been somewhat without organization, but comprehensive plans, with consideration for all the complicated factors involved, are now being worked out. Much of the valley floor can not be farmed because of periodic overflow. In addition to protection from surplus waters, drainage has been supplied to relieve certain soils of sluggish internal drainage. The systems are in most cases effective and of the open-ditch type, drainage water being largely pumped from the area over the inclosing levees. Such drainage will be necessary for other areas of low basin land now being reclaimed from overflow. Water storage in properly placed reservoirs will no doubt aid in the problem of protecting the main valley trough from floods, and many of the valley slope soils from intermittent overflow.

In the Sacramento Valley large areas are affected by injurious quantities of alkali. The largest amount is found on the west side of the valley, in regions of low gradient and stagnated drainage, bordering the "basins" of that locality. The reclamation of these soils involves a large expense. Important areas of alkali soils also occur in the southeastern part of the survey. The character of the alkali, its distribution in the soil column, and the quantities present vary greatly, and no specific method of reclamation will apply in all cases. In general, thorough drainage is the first requisite. In some places tile drainage is necessary and in others open ditches are sufficient.





[PUBLIC RESOLUTION—No. 9.]

JOINT RESOLUTION Amending public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, "providing for the printing annually of the report on field operations of the Division of Soils, Department of Agriculture."

*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled,* That public resolution numbered eight, Fifty-sixth Congress, second session, approved February twenty-third, nineteen hundred and one, be amended by striking out all after the resolving clause and inserting in lieu thereof the following:

That there shall be printed ten thousand five hundred copies of the report on field operations of the Division of Soils, Department of Agriculture, of which one thousand five hundred copies shall be for the use of the Senate, three thousand copies for the use of the House of Representatives, and six thousand copies for the use of the Department of Agriculture: *Provided*, That in addition to the number of copies above provided for there shall be printed, as soon as the manuscript can be prepared, with the necessary maps and illustrations to accompany it, a report on each area surveyed, in the form of advance sheets, bound in paper covers, of which five hundred copies shall be for the use of each Senator from the State, two thousand copies for the use of each Representative for the congressional district or districts in which the survey is made, and one thousand copies for the use of the Department of Agriculture.

Approved, March 14, 1904.

[On July 1, 1901, the Division of Soils was reorganized as the Bureau of Soils.]

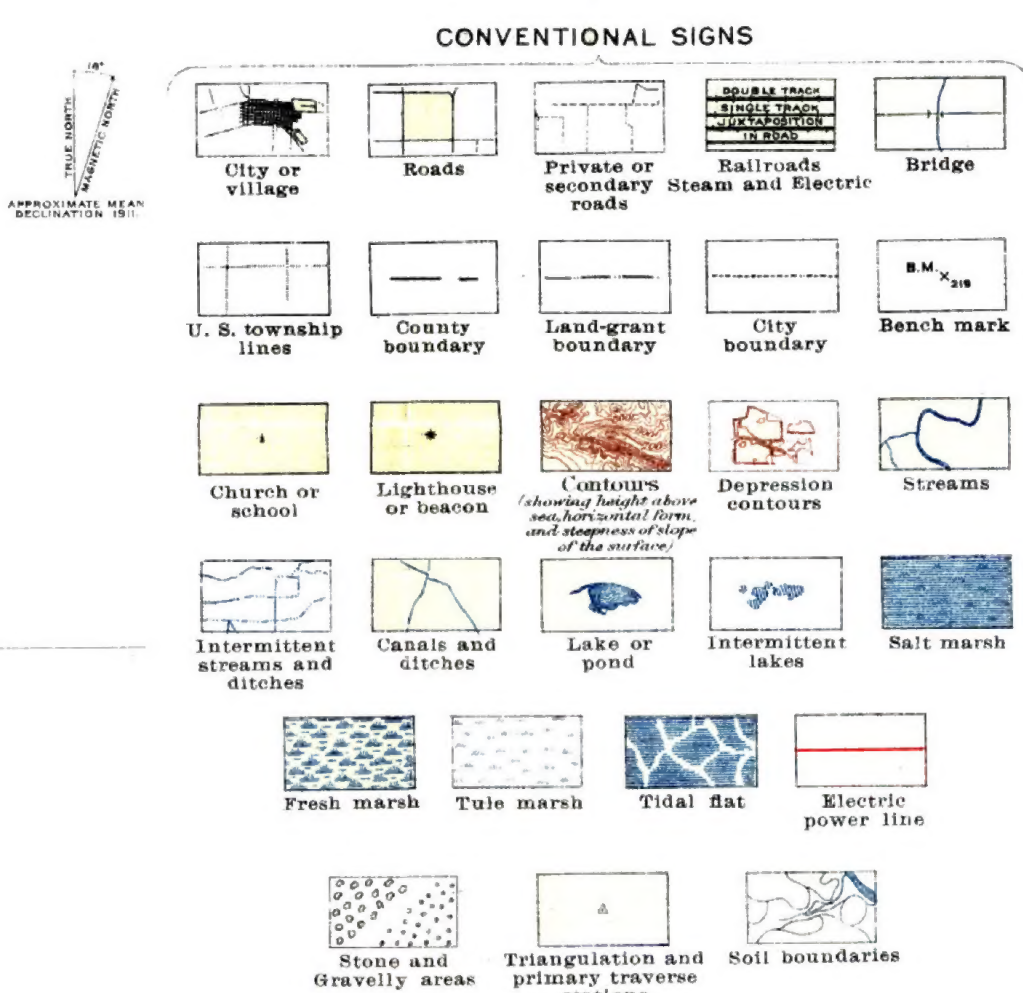
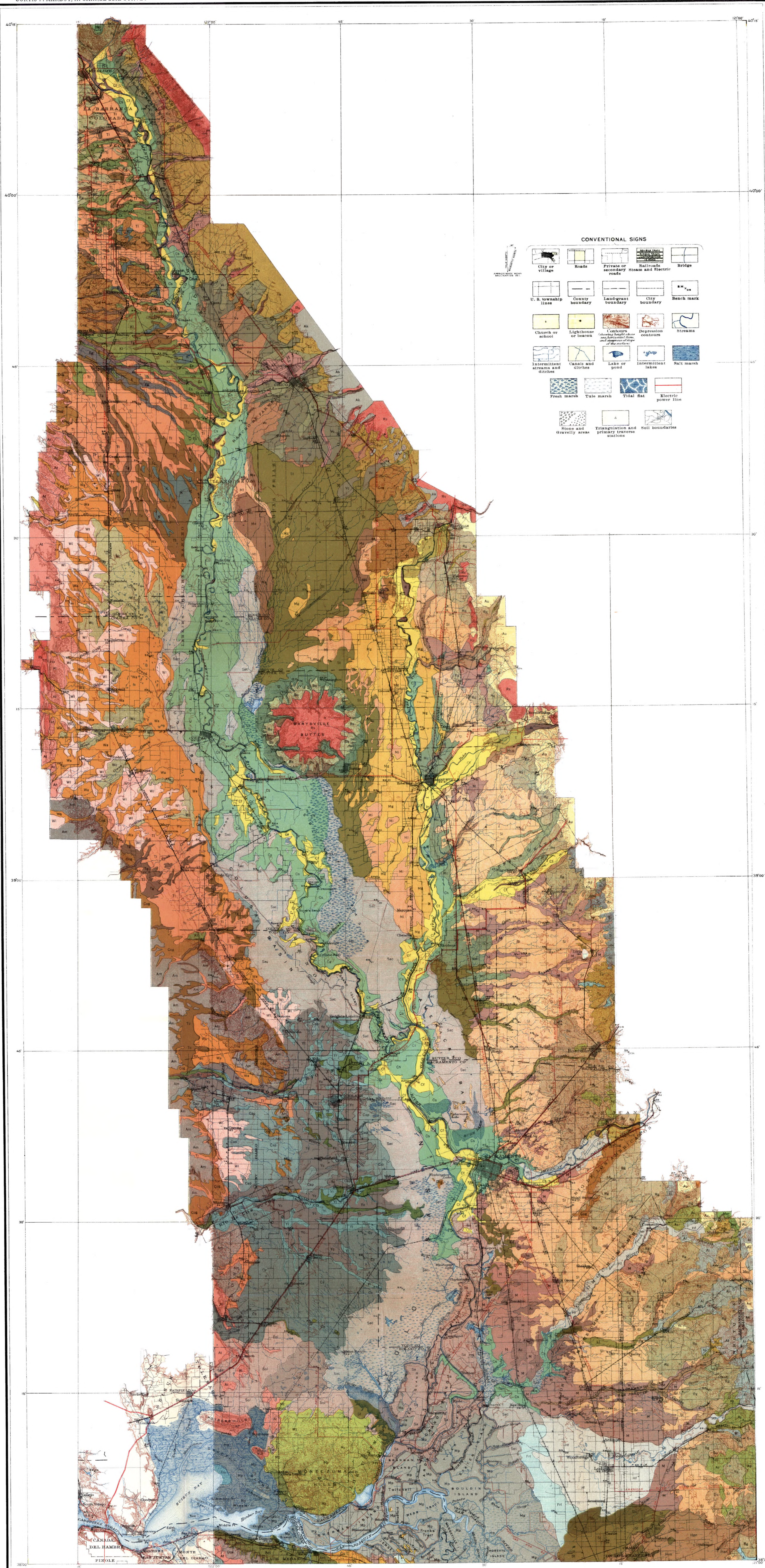
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LEGEND	
Aiken stony soils (undifferentiated)	Ak
Aiken loams	Al
Arnold loams shallow phase	Al
Arnold sandy loam	Al
Madera loams	M
Madera clay loams	Mc
Madera and Gridley loams (undifferentiated)	Mg
Madera and Gridley clay loams (undifferentiated)	Md
Antioch loam and clay loam	Am
Antioch and Montezuma soils (undifferentiated)	Am
Sutter loams	S
Sutter clay loam adobe and clay	Sc
Yolo loams	Yl
Yolo fine sandy loam	Yf
Yolo clay loam and clays (undifferentiated)	Yc
Tehama loams	Tl
Tehama gravelly loams	Tg
Tehama clay loams and clay	Tc
Capay clays	Cp
Capay and Yolo clay loams and clays (undifferentiated)	Cy
Willows loams	Wl
Willows fine sandy loam	Wf
Willows clay adobe	Wa
Willows clay	Wc
Vina loams	Vi
Vina gravelly loams shallow phase	Vg
Vina fine sandy loam	Vf
Vina clay loams	Vc
Vina clay adobe	Va
Laguna loam and clay loam	Ll
Laguna clay adobe	Lc
Riverwash	Rw
Muck and Peat	Mp
Solano loam and clay loam	Sl
Solano clays	Sd
Sacramento clay loams	Sa
Sacramento clays	Sac
Columbia fine sandy loams and sands	Cf
Columbia silt loams	Cs
Elder gravelly loams	El
Elder sandy clays loams (undifferentiated)	Es
Elder silt loams	Es
Stockton clay loam	St
Stockton clay adobe	Sc
Sierra sandy loams and loam (includes areas of Shasta, Colusa, and Siskiyou, and undifferentiated)	Si
Butte stony soils (undifferentiated)	Bs
Mariposa silt loam	Mar
Diablo clay adobe	Dc
Altamont soils (undifferentiated)	At
Oakley sand	Os
Tucson stony loams	Tu
Alamo clay adobe	Al
Corning gravelly loam	Cg
Kinball loam	Kl
San Joaquin loams	Sj
San Joaquin and Arnold loams (undifferentiated)	Sa
Bodding gravelly loams	Bd
Fresno loams	Fr
Hanford fine sandy loam	Hf
Kirkwood clay adobe	Kc
Gridley loams	Gr
Honcut loams	Ho
Rough stony land	Rl
Montezuma clay adobe	Mz
Tidal marsh	Tm
Tailings	Tl